Advances in Higher Education

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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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ISBN: 978-84-9048-496-8 (print version)
Print on demand

Abstract

Higher education institutions play an important role as leaders in knowledge creation and dissemination by setting the grounds for society to advance and to improve welfare. Despite the long-standing tradition of some higher education systems, Higher Education continuously evolves to adapt to the challenges that current societies open up to.

The objective of this book is to capture some recent advances made in Higher Education by addressing these challenges. To do so, some specific topics related to the inputs, outputs and process of education in Higher Education were selected to be analysed by a scientific research approach.

The book is arranged in five parts in accordance with these topics. Part I is related to the most important input of higher education institutions, that is, students, and particularly to address students' preparation when they access higher education studies. The next three parts of the book analyse different aspects of the learning process that take place in Higher Education. Part II assesses student learning from different points of view. Part III contains two chapters on the creation and availability of resources in higher education institutions. Part IV describes and analyses some innovative teaching and learning methods. Finally, Part V consists of three chapters that deal with the relation of Higher Education with industry, which is the main destination of graduates.

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Chapter 1
Introduction

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Higher education institutions play an important role as leaders in knowledge creation and dissemination by setting the grounds for society to advance and to improve welfare. Despite the long-standing tradition of some higher education systems, Higher Education continuously evolves to adapt to the challenges that current societies open up to.

One of these challenges is related to the increasing use of ICTs in everyday life, which obviously includes classrooms. Technologies enable new interaction modes in the educational process, and also reduce the cost of disseminating information. All this, in turn, allows knowledge to reach more and more people, which thus democratises knowledge. However, this adoption of technology needs to be properly managed in order to improve the learning experience.

Nevertheless, technology is not the only factor that opens up challenges in Higher Education. Today's social and economic trends also force institutions to adapt to the new reality. In particular, the globalisation and internationalisation of economies also affect how higher education institutions should design their programmes. It is now when instructors should focus on skills more than on contents. Students should be prepared for learning not only during their training period, but also after they have left university.

The objective of this book is to capture some recent advances made in Higher Education by addressing these challenges. To do so, some specific topics related to the inputs, outputs and process of education in Higher Education were selected to be analysed by a scientific research approach.

The book is arranged in five parts in accordance with these topics. Part I is related to the most important input of higher education institutions, that is, students, and particularly to address students' preparation when they access higher education studies. Chapter 2 analyses whether the use of ICTs can improve student performance in maths and financial education before they access university studies. Chapter 3 reviews how a cultural background can affect most of students' skills, such as autonomous learning. The last chapter in this part, Chapter 4, is about the motivation of students for them to engage in science and research.

The next three parts of the book analyse different aspects of the learning process that take place in Higher Education. Part II assesses student learning from different points of view. Chapter 5 deals with problem-solving skills and competence assessments in engineering studies. Chapter 6 focuses on how to reflect on how the received assessment can improve the learning process. Chapter 7 centres on the consistency of exams that combine different question types. Chapter 8 introduces a classification scheme of errors in student activities as a way to find and solve their difficulties. The last chapter in this part, Chapter 9, continues with the systematisation of the assessment and discusses rubrics as a tool to guide students and markers.

Part III contains two chapters on the creation and availability of resources in higher education institutions. Chapter 10 focuses on how to design incentives to promote the creation of open educational resources which, eventually, are economically efficient. Chapter 11 focuses on the educational resources that can be created when the academia approaches professional and scientific associations.

Part IV describes and analyses some innovative teaching and learning methods. Across emerging learning methods, project-based learning is attracting more attention. In this vein, Chapters 12 and 13 describe and analyse two different experiments with this methodology for preparing future engineers. Chapter 14 also deals with teaching methods for engineers, but focuses on using simulations to help students understand complex models. The last chapter of this part, Chapter 15, describes an experiment as to how to motivate engineering students when covering topics that differ from core technical contents, such as legal issues, which are essential in their professional life.

Finally, Part V consists of three chapters that deal with the relation of Higher Education with industry, which is the main destination of graduates. Chapter 16 explores the potential of MOOCs to connect Higher Education and professional practice. Chapter 17 focuses on checking whether curricular designs follow industry trends. Finally, Chapter 18 re-analyses the links between industry and universities in the engineering professional practice context.

PART I
Access to Higher Education

Chapter 2

How financial education affects Mathematics performance? Evidence from Spain in the context of the Program School 2.0

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Abstract: In this paper we evaluate the effect of participation in the Program School 2.0 on both Financial Education and Mathematics performance using data from PISA 2012. The School 2.0 Program was implemented in 2009 in some Spanish Autonomous Communities. This program promoted the use of computers, both in school and at home, among elementary and high school students. We detect that a greater benefit is obtained when the contents of Financial Education are taught in conjunction with the contents of the subject of Mathematics. Moreover, the inclusion of financial contents in Mathematics subject could help to alleviate the gender gap (school-boys vs. school-girls) and the nationality gap (native vs. immigrant students) observed in Mathematics performance. Regarding the influence of ICT on the skills for both subjects, the benefit of having a computer for personal use by students is observed, both for school and home use. However, it only has a positive effect on performance when it is used occasionally. However, we must interpret the results with certain caution, as not much time has passed since the implementation of these new teaching methodologies, so we should expect to see a "learning effect" over time.

Keywords: Program evaluation; PISA; Financial Education; Mathematics

Introduction

Adopting information conscious habits for savings and investment are the basis for enjoying economic prosperity. In contrast, fallout after borrowing money and the accumulation of debt not only poses a threat to family's economic stability, but it can also endanger economic progress at national level (Mandell, 2008). The recent economic and financial crisis has demonstrated that economic recovery requires the participation of all economic stakeholders (Lester and Williams, 2010). In this sense, during the Third National Meeting on Economic and Financial Education, Frederic Mishkin (2008), member of the Board of Governors of the Federal Reserve of the United States, declared that it would be difficult to find itself in a more propitious moment than the present, in order to demonstrate that a better understanding by citizens of the economy and finance could have reverted the situation through more wise decision-making. But, how is it possible that citizens become aware of the consequences of their financial decisions, if they lack financial education?

Financial Education enables the individual to acquire a series of very useful skills for adulthood and this should be a component of student learning. Studies have indicated that people who have received Financial Education show a greater tendency to manage their savings before retirement (Cole *et al.*, 2010), participate more in the stock markets, depict better optimizing behaviors for their stock portfolios (Van Rooij *et al.*, 2011), and take greater care when choosing mortgages or loans with lower interests and fees (Lusardi and Tufano, 2009).

Nowadays, students face a greater number of financial decisions than we could have ever imaged. For example: (i) the use of mobile phones means having to decide between either pre-paid plan or a contract and the responsibility to monitor their own consumption, (ii) the preference of receiving money instead of a gift on their birthday or some other important date, (iii) the management of money periodically, whether or not it is given to them by their parents, for expenses such as going out with friends, clothes, trinkets, etc. Moreover, ICTs (Information and Communication Technologies) play an important role in the lives of students and it is also required that they are prepared to make financial decisions involving the use of new technologies: (i) decide whether to buy a CD or purchase some of their favorite songs on-line, (ii) buy concert tickets online etc.

The OECD (2005) report had already indicated that the skills and abilities developed from Financial Education are so important that should be included within the curriculum of all schools. PISA (2012) provides the opportunity to analyze the importance of Financial Education as a tool to solve real life problems.

We have empirical evidence, as indicated by Varcoe *et al.* (2005), Hinojosa *et al.* (2009) and Lusardi and Mitchell (2009), which demonstrates that the incorporation of Financial Education into the academic curriculum has a positive impact on young people and facilitates the development of skills in the areas of savings, loans, investments, critical thinking and problem solving. In fact, New Zealand has not only introduced Financial Education into the school curriculum of Secondary Education, but there exist also elective subjects for learning Accounting (Samkin *et al.*, 2012). Moreover, Pinto *et al.* (2005) analyzed four elements (family, friends, schools and communication media) in order to determine which of these exerted the greatest influence on the adoption of financial culture by students. They found that parents and schools were the two most important forces, since students spend much of their day at school and it is there where the core of financial learning should be found.

This article jointly analyzes the relationship between performances in Mathematics and Financial Education, subject to their participation in School Program 2.0. Nowadays, computers are an essential instrument in the workplace and a certain mathematical literacies are required for effective practice in modern life (Hoyles *et al.*, 2002). Given that mathematical literacy is so completely intertwined with computer literacy, we will try to asses if the implementation of the Program School 2.0 in Spain has improved Mathematics achievement.

We analyze the interplay of the performance in both subjects using a bivariate probit model. The decision to consider simultaneous performances between the two subjects has a dual motive. First, PISA (2012) evaluates performance in Mathematics and some studies, such as Suiter and McCorkle (2008), have found that the melding of Mathematics and Financial Education favors the development of responsible financial behaviors. Second, the majority of problems that students need to solve on the PISA-Financial questionnaire (responding to real-life situations) require the completion of numerical calculations. Table 1 shows three examples of PISA-Financial problems.

Table 1. PISA-Financial Sample Questions (2012)

Exercise 1. The Market

John can buy individual or boxes of tomatoes. A kilogram of tomatoes costs 2.75 zeds and a 10 kilogram box of tomatoes costs 22 zeds. John says: "It is better to buy a box of tomatoes than to buy handpicked tomatoes." Provide an argument to support this claim.

Possible answers that could obtain a maximum score:

- It costs 2.75 zeds per kilogram for handpicked tomatoes, but only 2.2 zeds per kilogram for tomatoes in cases.
- It costs only 2.20 per kilogram for a case.
- Because 10 kilograms of handpicked tomatoes would cost 27.50 zeds.
- You get more kilos for each zed that you spend.
- Handpicked tomatoes cost 2.75 per kilo, but the tomatoes in cases cost 2.2 per kilo.
- It's cheaper per kilo. [This generalization is acceptable.]
- It’s cheaper per tomato. [The assumption that tomatoes are of the same size is acceptable.]
- You get more tomatoes per zed. [This generalization is acceptable.]

Exercise 2. Travel Money

Natalie works in a restaurant 3 afternoons a week. Every afternoon, she works 4 hours and earns 10 zeds per hour. Every week, Natalie also gains 80 zeds in tips. Natalie saves exactly half the total amount of money that she makes every week. Natalie wants to save 600 zeds to go on vacation.

How many weeks it will take Natalie to save 600 zeds?

Answer with maximum score: 6 (written answer)

Exercise 3. New Offer

Ms. Janeiro has a loan for 8,000 zeds from Primazed Bank. The annual interest rate for the loan is 15%. Monthly payments are 150 zeds. After a year, Ms. Janeiro still owes 7,400 zeds. Another financial company called Zedsuper, offers Ms. Janeiro a loan for 10,000 zeds with an annual interest of 13%. Monthly payments would also be 150 zeds.

What possible financial disadvantage may Ms. Janeiro have if she accepts a loan from Zedsuper?

Possible answers that could obtain a maximum score:

- She would owe more money.
- You will not be able to manage her expenses.
- She is getting into even more debt.
- 13% on 10,000 is more than 15% on 8,000.
- It may take longer to pay it off, because the loan is larger and monthly payments are the same.
- She may have to pay Primazed a penalty for paying back the loan sooner.

Source: The questions refer to a fictitious country Zedland, where the zed is the currency. Students receive this information at the beginning of the test.

Material and Methods

Program School 2.0

In July 2009, the Spanish Education Sector Conference approved a budget of €98,182,419 for the implementation of the Program School 2.0 (Resolution of 3rd August, 2009, of the Technical Secretariat General, with respect to the Agreement of the Council of Ministers of 31st July, 2009).

The allocation of these funds was to co-finance 50% of the following activities, within the Autonomous Communities: (1) The transformation of all 5th and 6th Primary Education and all 1st and 2nd Compulsory Secondary Education classrooms into digital classrooms at public schools; (2) The provision of computers for personal use, (3) The development of digital contents that may could be used by teachers. However, the Autonomous Communities' participation in School Program 2.0 was not homogeneous and three levels of participation were discernible:

(i) Total Participant Communities (TP): Andalusia, Aragon, Cantabria, Castile-Leon, Castile-La Mancha, Catalonia, Extremadura, Galicia, Navarra, Basque Country, La Rioja, Ceuta and Melilla

(ii) Partial Participant Communities (PP): Asturias, Balearic and Canary Islands. These one will not be considered in the following analysis.

(iii) Non-participat Communities (NP): Madrid, Murcia and the Valencian Community.

With the data of total expenditure by Autonomous Region and the number of students who have received a computer, the ratio of "investment per student" can be calculated (Table 2). This ratio must be understood in a broader sense, since it not only reflects the value of computer equipment received by the student has received, but also the appropriate allocation of expenditure on the digitization of classrooms and teacher training. On average, School Program 2.0 represents an investment of €476.1 per student (not only including the student's computer, but also the digitization of classrooms and teacher training), with a maximum of €1,840.8 for Navarre and €1,201.7 for Galicia, and a minimum of €142.3 for the Basque Country.

To appreciate the magnitude of this data, it has been compared with expenditure per ESO student in public schools in 2010. On average, students of School Program 2.0 have received an investment of 5,3% with respect that of an ESO student at a public school, with a maximum of 20% in Navarra and a minimum of 1.6%in the Basque Country.

Table 2. Estimated expenditure per Student within School Program 2.0 Compared to the Average Expenditure per Student in Compulsory Secondary Education and Public Schools

	Total Expenditure School Program 2.0. (1)	Computers for Students (2)	Investment per student (3)=(1)/(2)	Investment per Student within School Program 2.0 with respect to Public Expenditure per Public Student
Andalusia	70,081,420	282,082	248.4	0.027
Aragon	9,832,459	17,006	578.2	0.064
Asturias	6,383,629	14,568	438.2	0.048
Balearic Islands	7,718,435	27,050	285.3	0.032
Canary Islands	16,983,532	26,139	649.7	0.072
Cantabria	3,987,342	4,390	908.3	0.100
Castile and Leon	18148363	19,275	941.5	0.104
Castilla-La Mancha	18,928,362	43,250	437.6	0.048
Catalonia	53,191,112	100,209	530.8	0.059
Valencian Community	22,919,873	-	-	-
Extremadura	10,202,075	22,047	462.7	0.051
Galicia	18,026,168	15,000	1201.7	0.133
Madrid	23,022,965	-	-	-
Murcia	8,273,915	12,307	672.3	0.074
Navarra	5,065,906	2,752	1840.8	0.203
The Basque Country	5,665,355 (*)	39,826	142.3	0.016
La Rioja	2,315,613	4,103	564.4	0.062
Ceuta and Melilla	1,383,066 (**)	4,545	304.3	0.034
Total	302,129,589	634,549	476.1	0.053

The number of computers per student is considered as a representation of the number of students who have benefited from School Program 2.0. The ratio between column (1) and (2) represents the average investment per student, including not only a computer but also the digitization of classrooms and teacher training.

Annual public expenditure per student in public secondary education (2010). (Facts and Figures. School Year 2013/2014. Ministry of Education, Culture and Sports; pg. 11).

Econometric model

We consider two latent variables FE_i^* and MAT_i^* that denote "knowledge in Financial Education" and "knowledge in Mathematics", respectively. Both variables are influenced by observable characteristics (family group, resources available at home and at the school) and unobservable characteristics (innate aptitudes of students or their level of motivation). Additionally, the relationship between them can flow in both directions. On the one hand, Financial Education can provide a more applied perspective for certain mathematical concepts, so it can be useful to reduce the degree of abstraction that is so often argued as a difficulty by students when dealing with exact sciences. Moreover, students with a greater ability for numerical reasoning may find it easy and attractive to choose the field of Financial Education. In general, the score obtained in both areas may be expressed using the following system:

$$FE_i^* = X_{1i}^{'}\beta_1 + \varepsilon_{1i} \tag{1}$$

$$MAT_i^* = \alpha EF_i^* + X_{2i}^{'}\beta_2 + \varepsilon_{2i} \tag{2}$$

where $X_{1i}^{'}$ and $X_{2i}^{'}$ are vectors of observable characteristics, β_1 and β_2 are vectors of parameters, ε_{1i} and ε_{2i} are both error terms, which we assume follow a bivariate normal distribution with zero mean, unit variance and correlation coefficient ρ:

$$\begin{pmatrix}\varepsilon_{1i}\\ \varepsilon_{2i}\end{pmatrix} \sim N\left(\begin{pmatrix}0\\0\end{pmatrix}, \begin{pmatrix}1 & \rho\\ \rho & 1\end{pmatrix}\right) \tag{3}$$

and such that $E[X'_{1i}, \varepsilon_{1i}] = 0$ and $E[X'_{2i}, \varepsilon_{2i}] = 0$. Thus, if ρ is equal to zero, FE_i^* is not endogenously determined and both equations may be solved separately.

The following explanatory variables were introduced in both equations: characteristics of the students and the family (gender, nationality, repetition of grade level, availability of a computer at home, educational level of parents), and characteristics of the school (average class size, ratio of schoolgirls at the school, size of municipality). In the equation for MAT, we considered the following explanatory variables: if there is a school-policy on the use of computers in the classroom and on the quality assessment of Mathematics, the percentage of teachers with ISCED5A qualifications, if the student has a computer in the classroom and the frequency of ICT use to do homework.

In the equation for FE, the following explanatory variables have been considered: if the contents of Financial Education are compulsory, if it is delivered within a specific subject (Mathematics, Economics, Social Sciences and Humanities), the length Finance Education has been delivered, if teaching staff of Financial Education belong to the school's faculty and if teachers have received specific training.

Regarding student environment, two instrumental variables were introduced taking as reference evidence from the literature on Financial Education (Pinto *et al.*, 2005; Williams, 2010): (i) a binary variable that takes value 1 if the student indicates talking to his/her parents almost every day or 1-2 times a week about financial issues (savings, household spending, banks, etc.) and (ii) a binary variable that takes value 1 if the student indicates earning money from working (tutoring, babysitting) or helping out in a family business.

However, we did not observe the level of knowledge in Mathematics and in Financial Education (FE_i^* or MAT_i^*), but rather the results of PISA (FE_i and MAT_i). PISA (2012) scores are based on calculations on a metric scale, with a 500 point average for all OECD countries and a standard deviation of 100 points. For a better understanding, they are usually divided into proficiency levels. This classification, recommended by PISA Technical Report is useful because it allows us to communicate about the proficiency of students in terms other than numbers.

The variable FE_i is an ordered variable that classifies the PISA-Financial results into 5 levels: (1) "lowest performers": less than 400.33 points, (2) "low performers": between 400.33 and 475.10 points, (3) "moderate performers": between 475.10 and 549.86 points, (4) "strong performers": between 549.86 and 624.63 points, and (5) "top performers": over 624.63 points.

The variable MAT_i is another ordered variable that classifies PISA-Mathematics results into 6 Levels: (1) "lowest performers": less than 357.7 points, (2) "low performers": between 357.5 and 420.1 points, (3) "low moderate performers": between 420.1 and 482.4 points, (4) "high moderate performers": between 482.4 and 544.7 points, (5) "strong performers" between 544.7 and 607 points and (6) "top performers": over 607 points. Observed variables are linked to the latent variables according to the following expressions:

$$FE_i = \begin{cases} 1 \; if \; FE_i^* < \omega_1 \\ 2 \; if \; \omega_1 < FE_i^* < \omega_2 \\ 3 \; if \; \omega_2 < FE_i^* < \omega_3 \\ 4 \; if \; \omega_3 < FE_i^* < \omega_4 \\ 5 \; if \; \omega_4 < FE_i^* \end{cases} \tag{4}$$

$$MAT_i = \begin{cases} 1 \; if \; MAT_i^* < \tau_1 \\ 2 \; if \; \tau_1 < MAT_i^* < \tau_2 \\ 3 \; if \; \tau_2 < MAT_i^* < \tau_3 \\ 4 \; if \; \tau_3 < MAT_i^* < \tau_4 \\ 5 \; if \; \tau_4 < MAT_i^* < \tau_5 \\ 6 \; if \; \tau_5 < MAT_i^* \end{cases} \tag{5}$$

Where $\omega_1 < \omega_2 < \omega_3 < \omega_4$ and $\tau_1 < \tau_2 < \tau_3 < \tau_4 < \tau_5$ are the cut-off points.

We proceeded to calculate two bivariate probit models. In the first one, the effect of EF on MAT is considered as a constant, and therefore, a standard ordered bivariate probit model was calculated. The second alternative is a bivariate probit with mixed effects assuming that the parameter α follows a normal distribution with mean μ_α and standard deviationσ_α. The denomination "mixed effects" makes reference to the existence of heterogeneity regarding the impact of FE over MAT across students. Considering that α follows a statistical distribution allow us to distinguish between those who are able to transform the skills gained in FE into better results in MAT, and also, those students with higher difficulty in cross-curriculum learning in MAT from skills learned in FE. With regard to computational aspects, the calculation for the standard model was done using the command proposed by Sajaia (2008), while for the model with mixed effects we have adapted the routine proposed by Buscha and Conte (2010).

Data

PISA is a cross-sectional study, conducted every three years that started in 2000 for 15 year old students, with the purpose of evaluating their performance in the areas of mathematics, reading and science, as well as cross-curriculum problem solving skills. PISA does not consider students' knowledge in these areas in isolation, rather in relation to their ability to apply them to real world situations. In addition to the general module and the CBA module (computer based assessment), a third type of test was conducted to measure Financial Education performance.

PISA(2012) defines Financial Education as "the knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life." (OECD, 2014).

The sample for Spain contains 1,108 observations, but if we restrict the sample to public schools it becomes reduced to 765 observations. Regarding participation in School Program 2.0, there are 167 observations for non-participating communities (NP), 532 for totally participating Communities (TP) and 66 for partially participating Communities (PP). Due to the small number of observations for PP, the subsequent analysis shall focus only on NP and TP.

Descriptive statistics

Table 3 shows the descriptive statistics of the variables that are subsequently used in the econometric analysis, differentiating by type of participation in the School Program 2.0.

In relation to students' characteristics, the percentage of non-repeating students is greater in TP Communities (66.23%) compared to 54% for NP Communities. The percentage of immigrant students in NP Communities is substantially higher as compared to the TP Communities (12.08%). Around 90% of students of both types of Communities have a computer at home. However, the percentage indicating the use of a computer for doing homework "every day" or "almost every day" is higher in TP Communities (12.76%) as compared to NP Communities (8.5%).

As instrumental variables in the equation for Financial Education, we will use the habit of talking to parents about financial issues (on a frequent basis) and if the student is working (tutoring, babysitting, helping out with the family business). 26.80% of students in NP Communities indicated talking to their parents about financial issues (family situation, news, etc.) compared to 20% in TP Communities. Moreover, 18%-19% of students in TP and NP Communities do some kind of work.

The vast majority of schools of schools stated that they have a program that specifies Mathematics contents on a monthly basis. By contrast the existence of a policy for quality control of Mathematics was much less widespread (37% of NP and 45% of TP), as well as the use of computers in Mathematics classes (35% of NP and 37% of TP). Most schools do not deliver Financial Education contents in 4thESO (80.17% of NP, 65.38% of TP). Furthermore, only 12.13% of schools in NP Communities and 16.87% of TP Communities have a separate subject for Financial Education, while 22%-26% of schools teach the contents of Financial Education in a cross-curricular manner (i.e., within the curriculum of another subject or subjects).

Focusing on schools in which Financial Education is included within other subjects, a higher concentration was observed in Mathematics or Social Sciences/Humanities (40% of NP, 50% of TP), but the inclusion of Financial Education within Economics subject shows more disparity (18.22% in NP, 43.71% in TP).

The level of teacher qualification in Mathematics show significant differences between the Communities. 100% of Mathematics teaching staff has ISCED5A qualifications in NP Communities compared to 72.56% in TP Communities. Differences in classrooms' technical equipment are smaller: 70.30% of students in TP Communities have a computer in the classroom compared to 65.95% for NP.

Teaching staff who deliver the contents of Financial Education in TP Communities tends to belong to school's own faculty. Around 12% of teachers come from the private or public institutions or from NGOs. The percentage of teachers that have received specific training to deliver Financial Education during the last year is quite reduced (30% for TP and NP), and the same happens for the average number of training hours (38 hours/year in TP, 30 hours/year in NP).

Table 3. Descriptive Statistics

	Autonomous Communities Not Participating	**Total Participation by Autonomous Communities**
Student Characteristics		
School Boys	50.19	52.97
School Girls	49.81	47.03
Repeated grade level		
Has not repeated grade level	54.56	66.23
Has repeated a grade level	44.07	32.80
Has repeated two grade levels	1.37	0.97
Lives with only one parent	10.87	10.36
Lives with both parents	82.51	82.15
Immigrant	21.17	12.08
Foreign father	23.23	13.73
Foreign mother	26.39	15.66
Speak another language at home	21.42	19.30
Age upon arrival to Spain	14.49	8.07
Father’s education		
Has not completed ISCED1	2.55	4.13
ISCED1	14.65	12.08
ISCED2	21.61	24.27
ISCED3	4.37	0.81
ISCED4	18.38	23.05
ISCED5	15.05	11.02
ISCED6	16.68	18.97
Mother’s Education		
Has not completed ISCED1	3.00	3.27
ISCED1	14.82	13.83
ISCED2	26.57	19.97
ISCED3	3.24	1.81
ISCED4	23.24	24.40
ISCED5	9.81	11.81
ISCED6	16.33	21.71
Relationship between parental economic activity		
Father, employed	83.33	76.84
Father, unemployed	9.90	9.42
Father, other circumstance	3.67	7.11
Mother, employed	62.83	60.33
Mother, unemployed	8.37	10.94
Mother, other circumstance	25.28	25.50
During the past two weeks		
Missed a day of school	52.49	40.79
Late to school	38.93	33.31
Uses ICT to complete homework		
Never	36.76	36.24
1-2 times/month	30.41	20.52
1-2 times/week	17.79	22.38
Almost every day	5.52	8.92
Everyday	2.98	3.84
Availability of computer/tablet	90.00	92.40
More than 100 books at home	35.30	41.99
Talk to parents about financial issues	26.80	20.75
Student works or helps with family business	18.76	19.00
School Characteristics		
Educational policy for school		
Quality control for Mathematics	37.89	45.52
Use of computers	35.12	37.10
Same textbook for all students	81.55	62.24
Specification of monthly content	93.53	91.10
Class Size	25.20	26.66
Availability of computer/tablet	65.95	70.30
Proportion of schoolgirls in class	42.84	48.21
Teachers with ISCED5A qualifications	100.00	72.56
Location of school		
City (over 1,000,000 pop.)	12.54	12.92
City (100,000-1,000,000 pop.)	21.20	30.26
City (15,000-100,000 pop.)	44.99	31.90
Town (3,000-15,000 pop.)	21.27	21.26
Rural areas (less than 3,000 pop.)	0.00	3.67

Financial Education		
Availability of Financial Education		
Not available	80.17	63.58
Available less than 2 years ago	8.28	9.47
Available 2 or more years ago	11.55	25.83
Compulsory subject	0.00	17.17
Teaching Financial Education (Multiple answers possible)		
Independent subject	12.13	16.87
Cross-curricular subject	22.02	26.70
Within Economics subject	18.22	36.98
Within Mathematics subject	41.55	49.75
Within other subjects (Humanities or Social Sciences)	42.87	52.09
Extra-curricular activity	3.10	2.07
Within personal tutor classes	15.44	8.62
Who delivers Financial Education		
School teaching staff	68.98	78.68
Professionals in the public and private sectors or NGO	12.98	12.43
Teaching staff have participated in professional development activities (Finance area)	30.46	32.10
Average number of hours	30.81	38.02
N	167	532

Tables 4 to 7 show the cross tabulation of the scores in Mathematics and Financial Education in Communities with total participation in School Program 2.0 and non-participating Communities, and for repeating and non-repeating students. Scores in Mathematics and Financial Education have been tabulated according to the levels proposed by the OECD (2014).

For non-repeating students, we appreciate that the percentage of students with Levels 4 or 5 in both subjects is lower in TP Communities (26.54%) compared to 31.95% in NP. We also find a similar concentration of students with low scores in both Communities, since the percentage of students who have Level 1 or 2 in Financial Education, and at the same time, lower than 1, Level 1 or Level 2 in Mathematics is 9.23% for TP Communities compared to 10.30% for NP.

Finally, there are some atypical cases in TP Communities: high performance in Financial Education but, very low in Mathematics (0.56% of Students with Level 3 in Financial Education, but only Level 1 in Mathematics; 0.56% of students with Level 4 in Financial Education and only Level 2 in Mathematics), or vice versa, a high performance in Mathematics, but very low in Financial Education (0.28% with Level 1 in Financial Education and Level 4 in Mathematics).

Table 4. Ranking of Mathematics and Financial[1] Education Levels. Communities with Total Participation in School Program 2.0. Non-repeating students (%)

	Mathematics						
Financial	Below Level 1 Less than 357.7	Level 1 Between 357.7 and 420.1	Level 2 Between 420.1 and 482.4	Level 3 Between 482.4 and 544.7	Level 4 Between 544.7 and 607	Level 5 Over 607	**Total**
Level 1 Less than 400.33	1.12	4.47	1.12	0.00	0.28	0.00	6.98
Level 2 Between 400.33 and 475.10	1.68	1.96	6.15	2.79	1.40	0.00	13.97
Level 3 Between 475.10 and 549.86	0.56	2.51	12.29	13.69	4.47	0.00	33.52
Level 4 Between 549.86 and 624.63	0.00	0.56	3.91	10.61	9.50	0.84	25.42
Level 5 Over 624.63	0.00	0.00	0.00	3.91	7.82	8.38	20.11
Total	3.35	9.50	23.46	31.01	23.46	9.22	100.00

Table 5. Ranking of Mathematics and Financial Education Levels. Non-participating Communities in School Program 2.0. Non-repeating students (%)

	Mathematics						
Financial	Below Level 1 Less than 357.7	Level 1 Between 357.7 and 420.1	Level 2 Between 420.1 and 482.4	Level 3 Between 482.4 and 544.7	Level 4 Between 544.7 and 607	Level 5 Over 607	**Total**
Level 1 Less than 400.33	3.09	1.03	2.06	1.03	0.00	0.00	7.22
Level 2 Between 400.33 and 475.10	1.03	5.15	9.28	2.06	1.03	0.00	18.56
Level 3 Between 475.10 and 549.86	0.00	2.06	8.25	12.37	4.12	1.03	27.84
Level 4 Between 549.86 and 624.63	0.00	0.00	3.09	8.25	16.49	1.03	28.87
Level 5 Over 624.63	0.00	0.00	0.00	3.09	10.31	4.12	17.53
Total	4.12	8.25	22.68	26.80	31.96	6.19	100.00

A combined tabulation was conducted for students repeating 1 or 2 academic years in Tables 6 and 7. The percentage of students found within Levels 3, 4 or 5 in Mathematics and Levels 4 or 5 in Financial Education is similar for both communities: 14.37% in TP and 14.49% in NP.

There is a higher concentration of students with poor results in both subjects for TP Communities: 68.40% of TP Communities compared to 50.87% of NP Communities are found within Levels 1 or 2 of Financial Education and lower than Level 1, Level 1 or Level 2 in Mathematics.

[1] The classification conducted by OECD (2014) defines "Level 5" as scores ranging between 606.9 and 669.3 and "Level 6" for scores above 669.3, but given the small number of observations reaching Level 6, they have been included within Level 5.

Table 6. Ranking of Mathematics and Financial Education Levels. Communities with Total Participation in School Program 2.0. Repeating Students (%)

Financial	Mathematics						Total
	Below Level 1 Less than 357.7	Level 1 Between 357.7 and 420.1	Level 2 Between 420.1 and 482.4	Level 3 Between 482.4 and 544.7	Level 4 Between 544.7 and 607	Level 5 Over 607	
Level 1 Less than 400.33	17.82	14.37	8.05	0.00	0.00	0.00	40.23
Level 2 Between 400.33 and 475.10	3.45	10.34	14.37	2.30	0.00	0.00	30.46
Level 3 Between 475.10 and 549.86	0.00	3.45	8.05	8.05	1.15	0.00	20.69
Level 4 Between 549.86 and 624.63	0.00	0.00	2.30	4.60	0.00	0.00	6.90
Level 5 Over 624.63	0.00	0.00	1.15	0.00	0.00	0.57	1.72
Total	21.26	28.16	33.91	14.94	1.15	0.57	100.00

Table 7. Ranking of Mathematics and Financial Education Levels. Non-participating Communities in School Program 2.0. Repeating students (%)

Financial	Mathematics						Total
	Below Level 1 Less than 357.7	Level 1 Between 357.7 and 420.1	Level 2 Between 420.1 and 482.4	Level 3 Between 482.4 and 544.7	Level 4 Between 544.7 and 607	Level 5 Over 607	
Level 1 Less than 369.9	21.74	11.59	2.90	0.00	0.00	0.00	36.23
Level 2 Between 369.9 and 457.5	1.45	14.49	8.70	7.25	0.00	0.00	31.88
Level 3 Between 457.7 and 518.6	0.00	1.45	11.59	11.59	1.45	0.00	26.09
Level 4 Between 518.6 and 579.4	0.00	0.00	4.35	0.00	1.45	0.00	5.80
Level 5 Over 579.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	23.19	27.54	27.54	18.84	2.90	0.00	100.00

Results and Discussion

The results obtained from the analysis (with and without mixed effects) are shown in Table 8 for TP Communities and in Table 9 for NP Communities. In all models (with and without mixed effects), the correlation coefficient is significant and positive. Regarding the validation of the model with mixed effects, it is observed that the likelihood function is higher compared to the value of the function in the standard bivariate probit model. Furthermore, when calculating the impact of Financial Education on Mathematics as a function with mean (μ) and standard deviation (σ), both parameters are significantly different from zero for TP Communities and NP Communities. This result confirms the existence of substantial heterogeneity in the effect of Financial Education on the results of Mathematics among the students.

In both types of Communities, it is observed that non-repeating students (boys) and those who have a computer at home tend to obtain higher scores in Mathematics. However, having a computer/tablet for personal use in the classroom has a negative effect on Mathematics scores. In relation to this intriguing evidence, the analysis of the implementation of ICT in schools and high schools has sparked debate during the last decade. Some studies have appreciated a substantial improvement of students' achievement as a result of the introduction of ICT (Barro *et al.*, (2009) in United States and Carrillo *et al.* (2010) in Canada). However, other analyses have found an insignificant or even negative relationship between both variables. Golsbee and

Guryan (2002) concluded that a program implemented in United States aimed at increasing the computer-to-student ratio, had not had any significant effect over students' achievement. For Israel, Angrist and Lavy (2002) observed a negative effect of ICT over Mathematics scores for 4th grade students. Similarly, Leuven *et al.* (2004) concluded that the increase of computer-to-student ratio in Dutch schools had led to worse Language and Mathematics results.

When comparing mixed effect models, it is observed that the increase in Mathematics scores for non-repeating students and the reduction for immigrant students are considerably higher in NP Communities. Although female students and immigrants show poorer performance in Mathematics and Financial Education, the difference with respect to male students or non-immigrant students is lower in the area of Financial Education (as others authors have also noted, Martin *et al.*, 2007).

For the model with mixed effects in TP Communities, schools that have a policy concerning the use of computers in the classroom and quality assessment in Mathematics tend to score higher in this subject.

In relation to Financial Education score, the positive effect for male students is lower than the Mathematics one, while the negative effect experienced by immigrant students is lower for Mathematics. With regards to the placement of Financial Education in the teaching project, a positive effect is observed when there is an obligation to teach this subject and when it has been delivered for more than two years at the school. This last result may be related to the existence of learning outcomes within the teaching plans, since with an increased number of years of "running", teachers know better how to teach students.

Talking with parents about issues related to Financial Education or having a job are significant and positive variables, with the first one having great influence on the score of Financial Education. These results confirm the evidence obtained by previous literature.

The fact that teaching faculty corresponds to school teachers instead of professionals from public and private institutions or NGOs is not significant for TP Communities, but it has a positive influence for NP Communities. The percentage of teachers who have received specific training in Financial Education during the past year is not significant for TP Communities, however, it is for NP Communities.

Table 8. Estimation of Bivariate Ordered Probit Model for Mathematics and Financial Education Scores. Communities with Total Participation

	Without Mixed Effects			**With Mixed Effects**		
Mathematics	**Coef**	**Std.D**		**Coef**	**Std.D**	
Financial Education Score	1.215	0.069	***			
Student (boy)	0.457	0.103	***	0.433	0.193	***
Immigrant	-0.149	0.077	**	-0.339	0.090	***
Non-repeating	0.175	0.041	**	0.334	0.045	***
Use of Computers Policy	0.224	0.100	**	0.180	0.032	***
Mathematics Quality Policy	0.011	0.163		0.050	0.028	*
Average Class Size	0.005	0.007		-0.006	0.008	
Ratio of Schoolgirls	-0.928	0.360	**	-0.599	0.413	
Ratio of ISCED5A Teachers	0.142	0.110		0.181	0.143	**
Computer/tablet at home	0.349	0.117	***	0.431	0.218	**
Computer/tablet at school	-0.136	0.010	***	-0.146	0.035	***
ICT for homework						***
1-2 times/week	0.230	0.113	**	0.141	0.148	
Almost every day	-0.068	0.011	***	-0.245	0.105	**
Everyday	-0.440	0.241	**	-0.695	0.288	***
Financial Education						
Non-repeating	1.198	0.121	***	1.250	0.236	***
Student (boy)	0.363	0.091	***	0.315	0.102	***
Immigrant	-0.305	0.162	*	-0.238	0.108	*
Student talks to parents	0.092	0.011	***	0.172	0.011	***
Student works	0.041	0.071	**	0.102	0.026	***
Computer/tablet at home	0.454	0.205	***	0.239	0.146	***
Subject, less than 2 years ago	0.304	0.154	**	0.572	0.192	**
Subject, more that 2 years ago	0.407	0.202	**	0.635	0.188	**
Compulsory subject	0.276	0.155	*	0.664	0.207	*
Explanation						
Cross-curricular subject	-0.342	0.126	***	-0.403	0.177	***
Within Economics Subject	-0.331	0.013	**	-0.420	0.137	**
Within Mathematics Subject	0.270	0.065	***	0.221	0.103	***
Within Science or Humanities Subjects	-0.128	0.050	**	-0.093	0.177	**
Teacher Training Courses	0.042	0.139		0.086	0.135	
Teacher: Teacher from School	0.175	0.147		0.260	0.156	
Average Class Size	-0.016	0.006	**	-0.023	0.175	**
Ratio of Schoolgirls	-0.066	0.281		-0.017	0.007	
Interaction: Computer/tablet at school and Financial Education within Mathematics	-0.485	0.056	***	-0.602	0.289	***
Interaction: ICT for homework and Financial Education within Mathematics						
1-2 times/week	0.207	0.062	**	0.326	0.173	**
Almost every day	-0.192	0.082	**	-0.047	0.200	**
Everyday	-0.804	0.323	**	-0.147	0.278	**
Constant	-0.736	0.245	***	-0.935	0.445	***
μ(mixed effect)				1.222	0.254	***
σ(mixed effect)				0.653	0.287	***
ρ	0.627	0.149	***	0.351	0.178	***
Log likelihood		-1,174.959			-1,147.912	
N		532			532	

All cut-off points are significant at 5%. In both equations, the size of the municipality and the highest educational level of the father/mother have been included as an explanatory variable. Omitted variables: schoolgirls, repeating students, national, use computer for homework 1-2 times/month or less frequently, non-compulsory Financial Education, Financial Education subject not available. (***: Significant at 1%; **: significant at 5%; *: significant at 10%).

Table 9. Estimation of Bivariate Ordered Probit Model for Mathematics and Financial Education Scores. Non-participating Communities

	Without Mixed Effects			With Mixed Effects		
Mathematics	**Coef**	**Std.D**		**Coef**	**Std.D**	
Financial Education Score	1.291	0.142	***			
Student (boy)	0.688	0.199	***	0.624	0.201	***
Immigrant	-0.616	0.278	**	-1.844	0.419	***
Non-repeating	0.826	0.338	**	2.051	0.548	***
Use of Computers Policy	0.332	0.203		0.490	0.858	
Mathematics Quality Policy	0.547	0.371		1.670	2.336	
Average Class Size	-0.040	0.025		-0.142	0.199	
Ratio of Schoolgirls at class	-1.257	0.568		1.060	2.313	
Ratio of ISCED5A Teachers						
Computer/tablet at home	0.592	0.256	**	0.845	0.316	**
Computer/tablet at school	-0.064	0.021	***	-0.226	0.112	**
ICT for homework						
1-2 times/week	0.029	0.009	***	0.021	0.006	***
Almost every day	-0.049	0.024	**	-0.216	1.482	**
Everyday	-0.102	0.050	**	-0.614	0.201	***
Financial Education						
Non-repeating	1.180	0.210	***	1.240	0.189	***
Student (boy)	0.350	0.128	**	0.310	0.098	***
Immigrant	-0.503	0.272	*	-0.391	0.115	*
Student talks to parents	0.228	0.100	**	0.344	0.165	**
Student works	0.257	0.130	**	0.195	0.068	***
Computer/tablet at home	0.631	0.349	**	0.241	0.108	**
Subject, less than 2 years ago	0.121	0.016	***	0.798	0.378	**
Subject, more than 2 years ago	0.728	0.321	**	0.941	0.450	**
Compulsory subject	-	-		-	-	
Explanation						
Cross-curricular subject	-0.607	0.134	***	-0.214	0.064	***
Within Economics Subject	-0.670	0.216	***	-0.771	0.349	***
Within Mathematics Subject	0.105	0.038	***	0.297	0.084	***
Within Science or Humanities Subjects	-0.249	0.036	***	-0.242	0.015	***
Teacher Training Courses	0.786	0.279	***	0.952	0.445	***
Teacher: Teacher from School	0.789	0.382	**	0.808	0.323	**
Average Class Size	0.038	0.026		0.863	0.515	
Ratio of Schoolgirls at class	0.573	0.874		0.039	0.030	
Interaction: Computer/tablet at school and Financial Education within Mathematics	-0.434	0.132	***	-0.830	0.211	***
Interaction: ICT for homework and Financial Education within Mathematics						
1-2 times/week	0.184	0.067	***	0.180	0.063	***
Almost every day	-0.263	0.025	***	-0.350	0.075	***
Everyday	-0.337	0.067	**	-0.413	0.065	**
Constant	0.468	0.421		-0.998	0.572	**
μ(mixed effect)				1.410	0.308	***
σ(mixed effect)				0.257	0.081	***
ρ	0.751	0.178	***	0.271	0.101	***
Log likelihood		-360.159			-347.454	
N		166			166	

Same footnote than previous table.

When comparing the effect of Financial Education on Mathematics between the two types of Communities and models, we observe that Financial Education always has a significant and positive effect on the subject of Mathematics. The advantage of calculating a mixed effects model is that it is possible to differentiate the effect of Financial Education on Mathematics within the same group.

Figure 1 shows the density functions corresponding to the effect of Financial Education on Mathematics in TP and NP Communities. The mean effect of the Financial Education variable on Mathematics is more intense in NP Communities than for TP Communities (1.410 compared to 1.222) and it is also more concentrated. This implies that in TP Communities there are students who receive greater benefit from learning Financial Education in regards to Mathematics scores (30% of the distribution is above 2), but there are also students who are found in the opposite situation (10.62% are below zero), i.e., that obtain good results in Financial Education, but poor results in Mathematics.

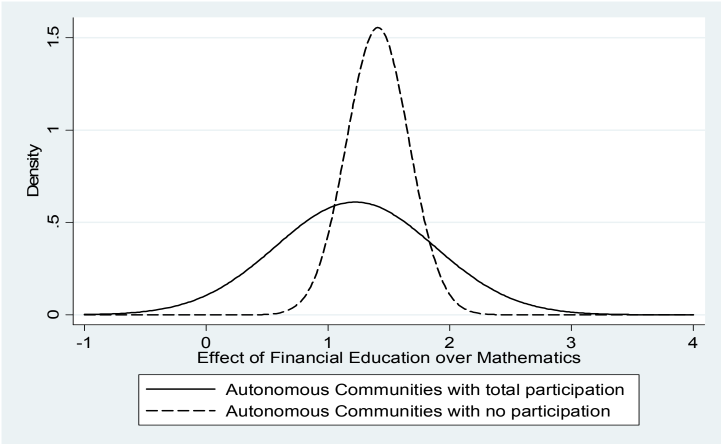

Figure 1. Density Functions of the Effect of Financial Education on Mathematics Scores According to Participation in School Program 2.0 (repeating and non-repeating students are included)

The sample size of the TP Communities allows the calculation of the bivariate probit model with mixed effects distinguishing between repeating and non-repeating students. We consider that this analysis is interesting given the relevant proportion of repeating students. The results of the estimation are not shown due to their size, but are available on request from the authors. Figure 2 shows the density functions for repeating and non-repeating students in TP Communities.

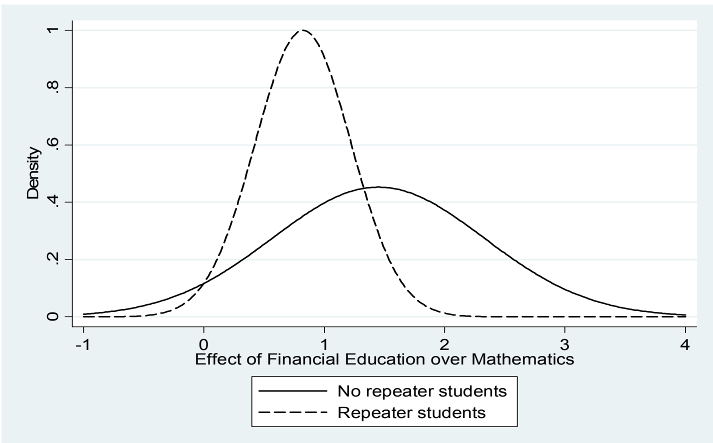

Figure 2. Density Functions of the Effect of Financial Education on Mathematics Scores According to Grade Repetition. Only Communities with Total Participation in School Program 2.0

The effect of Financial Education on Mathematics is, on average, 1.4491 for non-repeating students compared to 0.8234 for repeating ones. Consequently, in TP Communities, there is a multiplicative effect (which also might be described as a positive externality) of Financial Education over Mathematics for non-repeating students. However, for students who have repeated a school year, the transmission of knowledge or skills from Financial Education to Mathematics occurs at a lower rate (the sample size does not allow us to differentiate between students who have repeated one or two school years).

These results suggest that for some students the learning process operates like an osmosis system, in a manner that knowledge/skills from Financial Education are transferred to the field of Mathematics with a clearly positive effect. However, there are other students that seem to operate within a separate system: they “do" well in Financial Education but have less satisfactory results in Mathematics.

Predicted Probabilities for Financial Education

Table 10 shows the probability that Financial Education scores lies within Levels 1-5 depending on the teaching methodology, participation in the School Program 2.0 and repeating and non-repeating students.

Placement of Financial Education in relation to other subjects

For non-repeating students, the probability that Financial Education score lies within Levels 4 or 5 is higher when it is included within the subject of Mathematics (0.439 for TP and 0.566 for NP). In second place, when it is included within another subject of Social Sciences or Humanities (0.408 for TP and 0.493 for NP). It must be noted that if Financial Education is included within the subject of Mathematics, the probability of obtaining a score within Levels 4 or 5 is increased by 36.33% (TP) and 52.97% (NP) compared to its placement within the subject of Economics.

For non-repeating students, the probability that the Financial Education score lies within Level 1 is 0.519 (TP) and 0.426 (NP) if it is delivered within the subject of Economics, compared to 0.394 (PF) and 0.314 (NP) if it is included within the subject of Mathematics. Therefore, the probability of obtaining the lowest results is reduced by 24.08% (TP) and 26.29% (NP) when it is taught within the subject of Mathematics.

Utilization of Computers in the Classroom for Mathematics Classes

The interaction between the use of a computer in the subject of Mathematics and the placement of Financial Education within this subject reveals that the probability of obtaining Financial Education score within Level 4 or 5 decreases when the student has a computer/tablet for personal use (0.393 compared to 0.452 for TP and 0.398 compared to 0.518 for NP). In percentage terms, the use of computers in the subject of Mathematics implies a lower score in Financial Education by 15.26% for TP and 30.15% for NP. The fact that the reduction (in percentage terms) is greater in NP Communities may indicate different styles of teaching methodology applied to ICTs between Communities that have participated or not in School Program 2.0.

For repeating students of TP Communities, there are no significant differences in the distribution by Financial Education levels based on the use of computers in the classroom. In contrast, for NP Communities, the probability that the score for Financial Education lies in the lowest Levels (1 or 2) is 0.289 when using a computer compared to 0.204 when not used, which represents a reduction of 29.41%. As already mentioned, these differences according to Communities hint the existence of differences in the use that is given to ICT as a learning tool.

Utilization of a Computer to do Mathematics Homework

The relationship between the use of a computer for Mathematics homework and the inclusion of Financial Education within this subject reveals different patterns of behaviour in terms of the participation in School Program 2.0 and grade repetition.

For non-repeating students, the highest probability of obtaining a score within Level 4 or 5 for Financial Education corresponds to the use of a computer 1-2 times/week for TP Communities compared to 1-2 times/month or less for NP Communities. For TP Communities, the probability drops to a minimum (0.130) for the use of a computer every day, increases to 0.374 when it is used almost every day, peaks (0.497) at 1-2 times/week and decreases again to 0.430 when rarely used. For NP Communities, the probability of obtaining better results in Financial Education shows an inverse relationship with respect to its the frequency of use: 0.222 for daily use, 0.451 for almost everyday, 0.600 for 1-2 times/week and 0.677 for 1-2 times/month or less.

For repeating students, the greatest probability to achieve a score within Level 1 in Financial Education corresponds to computer daily use in TP Communities or almost everyday in NP. The lowest probability of obtaining a score within Level 1 is for using a computer for homework 1-2 times/week (0.251 for TP and 0.242 for NP).

Table 10. Predicted Probability for Financial Education Levels

	Total participation		No participation	
	No rep.	**Repeating**	**No rep.**	**Repeating**
Financial Education: Within Economics Subject				
Financial Compt. Score: Level 1	0.117	0.519	0.110	0.426
Financial Compt. Score: Level 2	0.209	0.260	0.223	0.306
Financial Compt. Score: Level 3	0.351	0.173	0.297	0.186
Financial Compt. Score: Level 4	0.201	0.039	0.233	0.066
Financial Compt. Score: Level 5	0.121	0.009	0.137	0.015
Financial Education: Within Mathematics Subject				
Financial Compt. Score: Level 1	0.068	0.394	0.040	0.314
Financial Compt. Score: Level 2	0.158	0.280	0.133	0.323
Financial Compt. Score: Level 3	0.334	0.236	0.261	0.238
Financial Compt. Score: Level 4	0.241	0.069	0.301	0.100
Financial Compt. Score: Level 5	0.198	0.021	0.265	0.026
Financial Education: Within Humanities or Social Sciences Subject				
Financial Compt. Score: Level 1	0.080	0.421	0.056	0.361
Financial Compt. Score: Level 2	0.171	0.278	0.166	0.314
Financial Compt. Score: Level 3	0.341	0.221	0.285	0.217
Financial Compt. Score: Level 4	0.232	0.061	0.283	0.086
Financial Compt. Score: Level 5	0.176	0.018	0.210	0.021
Financial Education: Extra-Curricular Activity				
Financial Compt. Score: Level 1	0.083	0.442	0.070	0.426
Financial Compt. Score: Level 2	0.177	0.282	0.190	0.317
Financial Compt. Score: Level 3	0.348	0.210	0.300	0.185
Financial Compt. Score: Level 4	0.229	0.053	0.271	0.061
Financial Compt. Score: Level 5	0.163	0.014	0.168	0.012
Availability of a computer/tablet in the classroom for the subject of Mathematics and Financial Education within the subject of Mathematics				
Financial Compt. Score: Level 1	0.083	0.413	0.084	0.392
Financial Compt. Score: Level 2	0.178	0.282	0.205	0.314
Financial Compt. Score: Level 3	0.346	0.226	0.313	0.203
Financial Compt. Score: Level 4	0.228	0.062	0.262	0.075
Financial Compt. Score: Level 5	0.165	0.018	0.136	0.016
Do not have a computer/tablet in the classroom for the subject of Mathematics and Financial Education is taught within the subject of Mathematics				
Financial Compt. Score: Level 1	0.064	0.405	0.049	0.279
Financial Compt. Score: Level 2	0.151	0.282	0.155	0.327
Financial Compt. Score: Level 3	0.332	0.230	0.278	0.255
Financial Compt. Score: Level 4	0.248	0.064	0.288	0.110
Financial Compt. Score: Level 5	0.205	0.018	0.230	0.029
Use of ICT for homework in Mathematics (1-2 times/week) and Financial Education within the subject of Mathematics				
Financial Compt. Score: Level 1	0.046	0.251	0.032	0.242
Financial Compt. Score: Level 2	0.132	0.283	0.121	0.290
Financial Compt. Score: Level 3	0.325	0.310	0.247	0.265
Financial Compt. Score: Level 4	0.262	0.114	0.297	0.148
Financial Compt. Score: Level 5	0.235	0.042	0.303	0.054
Use of ICT for homework in Mathematics (almost every day) and Financial Education within the subject of Mathematics				
Financial Compt. Score: Level 1	0.077	0.483	0.069	0.448
Financial Compt. Score: Level 2	0.186	0.280	0.186	0.280
Financial Compt. Score: Level 3	0.363	0.187	0.294	0.177
Financial Compt. Score: Level 4	0.228	0.040	0.274	0.074
Financial Compt. Score: Level 5	0.146	0.009	0.177	0.020
Use of ICT for homework in Mathematics (every day) and Financial Education within the subject of Mathematics				
Financial Compt. Score: Level 1	0.260	0.714	0.201	0.366
Financial Compt. Score: Level 2	0.302	0.194	0.312	0.321
Financial Compt. Score: Level 3	0.308	0.080	0.265	0.215
Financial Compt. Score: Level 4	0.099	0.010	0.142	0.081
Financial Compt. Score: Level 5	0.031	0.001	0.080	0.017
Use of ICT for homework in Mathematics (1-2 times a month or less) and Financial Education within the subject of Mathematics				
Financial Compt. Score: Level 1	0.070	0.402	0.011	0.383
Financial Compt. Score: Level 2	0.161	0.286	0.076	0.295
Financial Compt. Score: Level 3	0.339	0.231	0.236	0.215
Financial Compt. Score: Level 4	0.241	0.063	0.346	0.088
Financial Compt. Score: Level 5	0.189	0.018	0.331	0.019

Simulation of the Effects of an Increased Score in Financial Education

Tables 11 and 12 show the effects on Mathematics scores resulting from improved scores by 5, 10, 15 and 20 points in Financial Education. For non-repeating students, an increase in Financial Education scores by 5 points increases the probability that Mathematics scores would lie in the highest level (level 5) by 5.74% for TP Communities and 8.17% for NP Communities. If Financial Education scores increase by 10 points, the probability that Mathematics scores lies within Level 5 is increased by 11.82% and 15.22%, respectively.

For repeating students, the effects of an increase in Financial Education scores on Mathematics are higher for NP Communities. For example, an increase by 10 points raises the probability that Mathematics scores are found within Level 5 by 12.99% compared to 19.76 in NP Communities.

The differences between repeating and non-repeating students are particularly evident to encourage an increase by 20 points in Financial Education. The probability that Mathematics score lies within Level 5 increases by 21% for non-repeating students (for both types of Communities). However, for repeating students, the probability increases by 28.65% for TP Communities and by 65.49% for NP Communities.

Table 11. Simulation of the Effect on Mathematics Score as a result of an increase in the performance of Financial Education. Communities with Total Participation in School Program 2.0

	No rep.	Rep	Variation from Base Case (%)	
Base Case				
Mathematics Score: Level 1	0.087	0.305	-	-
Mathematics Score: Level 2	0.106	0.212	-	-
Mathematics Score: Level 3	0.206	0.233	-	-
Mathematics Score: Level 4	0.208	0.136	-	-
Mathematics Score: Level 5	0.393	0.114	-	-
Financial Education: +5				
Mathematics Score: Level 1	0.081	0.295	-6.96	-3.43
Mathematics Score: Level 2	0.101	0.208	-4.52	-2.01
Mathematics Score: Level 3	0.198	0.234	-3.68	0.60
Mathematics Score: Level 4	0.204	0.142	-1.95	4.38
Mathematics Score: Level 5	0.415	0.122	5.74	6.48
Financial Education: +10				
Mathematics Score: Level 1	0.075	0.277	-14.62	-9.19
Mathematics Score: Level 2	0.092	0.204	-13.05	-3.81
Mathematics Score: Level 3	0.188	0.239	-9.00	2.64
Mathematics Score: Level 4	0.207	0.151	-0.60	11.17
Mathematics Score: Level 5	0.439	0.129	11.82	12.99
Financial Education: +15				
Mathematics Score: Level 1	0.070	0.258	-20.07	-15.45
Mathematics Score: Level 2	0.085	0.203	-20.07	-4.29
Mathematics Score: Level 3	0.179	0.249	-13.27	6.66
Mathematics Score: Level 4	0.208	0.158	-0.07	16.41
Mathematics Score: Level 5	0.459	0.133	16.89	16.19
Financial Education: +20				
Mathematics Score: Level 1	0.065	0.247	-25.80	-19.06
Mathematics Score: Level 2	0.080	0.195	-24.30	-8.03
Mathematics Score: Level 3	0.173	0.247	-15.90	6.03
Mathematics Score: Level 4	0.207	0.164	-0.54	20.95
Mathematics Score: Level 5	0.475	0.147	20.94	28.65

Table 12. Simulation of the Effect on Mathematics Score as a result of an increase in the performance of Financial Education. Communities Not Participating in School Program 2.0

	Non-repeating	Rep	Change from base case (%)	
Base Case				
Mathematics Score: Level 1	0.070	0.247	-	-
Mathematics Score: Level 2	0.110	0.239	-	-
Mathematics Score: Level 3	0.192	0.271	-	-
Mathematics Score: Level 4	0.220	0.161	-	-
Mathematics Score: Level 5	0.407	0.083	-	-
Financial Education: +5				
Mathematics Score: Level 1	0.067	0.244	-4.54	-1.29
Mathematics Score: Level 2	0.102	0.229	-7.25	-4.00
Mathematics Score: Level 3	0.176	0.262	-8.26	-3.24
Mathematics Score: Level 4	0.214	0.170	-2.82	5.70
Mathematics Score: Level 5	0.441	0.095	8.17	14.90
Financial Education: +10				
Mathematics Score: Level 1	0.058	0.239	-16.82	-3.10
Mathematics Score: Level 2	0.091	0.221	-17.14	-7.53
Mathematics Score: Level 3	0.172	0.262	-10.53	-3.27
Mathematics Score: Level 4	0.210	0.179	-4.65	11.26
Mathematics Score: Level 5	0.469	0.099	15.02	19.76
Financial Education: +15				
Mathematics Score: Level 1	0.057	0.222	-18.55	-10.15
Mathematics Score: Level 2	0.089	0.206	-19.66	-13.68
Mathematics Score: Level 3	0.170	0.264	-11.42	-2.58
Mathematics Score: Level 4	0.208	0.191	-5.47	18.62
Mathematics Score: Level 5	0.476	0.117	16.86	42.00
Financial Education: +20				
Mathematics Score: Level 1	0.053	0.201	-24.53	-18.51
Mathematics Score: Level 2	0.085	0.193	-23.02	-19.20
Mathematics Score: Level 3	0.165	0.264	-14.41	-2.55
Mathematics Score: Level 4	0.202	0.205	-8.04	27.53
Mathematics Score: Level 5	0.495	0.137	21.60	65.49

Conclusions

This work has confirmed the importance that young people understand Financial Education concepts, not only because it involves a significant improvement for scores in this area, but also because it holds, to a great extent, a beneficial effect on the skills acquired within the subject of Mathematics. It has been shown that a greater benefit is obtained when the contents of Financial Education are taught in conjunction with the contents of the subject of Mathematics. Moreover, the inclusion of financial contents in Mathematics subject could help to alleviate the gender gap (school-boys vs. school-girls) and the nationality gap (native vs. immigrant students) observed in Mathematics performance. From the point of view of Higher Education, the main recommendation of this paper is that faculties preparing teachers for primary and secondary schools should include the standards of financial literacy and the relationship with mathematical concepts in their academic programs.

Regarding the influence of ICT on the skills for both subjects, the benefit of having a computer for personal use by students is observed, both for school and home use. This positive effect is associated with a moderate use of computers (1-2 times/week), but is not observed for the case of daily use. However, we must interpret the results with certain caution, as not much time has passed since the implementation of these new teaching methodologies, so we should expect to see a "learning effect" over time. In this case, future waves of PISA could be used to test this hypothesis.

Three relevant aspects are highlighted as areas for short-term improvements. First, the importance of school policy regarding the use of computers in the classroom, given that as PISA (2012) data reveal that less than half of schools have one. Second, the encouragement of teacher training, as only a small percentage of teachers have received specific instruction for teaching Financial Education. Thirdly, it has been verified that 100% of students in Communities that have not participated in School Program 2.0 have experienced a positive effect of Financial Education over Mathematics; meanwhile Communities with total participation had approximately 10% of students with mixed results in both areas.

Given that the analysis included variables related to the student, his/her family, the use of ICT as a teaching methodology, and the inclusion of Financial Education contents within subjects, we must consider which other variables (motivational, linguistic, procedural) are hindering student learning, since these deficiencies in their education could imply a major detriment to his/her subsequent development as an adult.

References

Angrist, J., Lavy, V. (2002). New evidence on classroom computers and pupil learning. Economic Journal, 112, 735-765.

Barrow, L., Nmarkman, L., Rouse, C. (2009). Technology’s edge: the educational benefits of computer-aided instruction. American Economic Journal: Economic Policy, 1(1), 52-74.

Buscha, F., Conte, A. (2010). The impact of truancy on educational attainment: a bivariate ordered probit estimator with mixed effects. JENA Economic Research Papers N0. 062. Volpe.

Carrillo, P., Onofa, M., & Ponce, J. (2010). Information technology and student achievement: evidence from a randomized experiment in Ecuador. Inter-American Development Bank Working Paper Series No. 223.

Cole, S., Sampson, T., Zia, B. (2011). Prices or knowledge? What drives demand for financial services in emerging markets? The Journal of Finance, 66, 1933-1967.

Golsbee, A., & Guryan, J. (2002). The impact of internet subsidies on public schools. NBER Working Paper No. 9090.

Hinojosa, T., Miller, S., Swanlund, A., Hallberg, K., Brown, M., O’Brien, B. (2009). The Stock Market Game study: a brief report. Washington, DC: FINRA Investor Education Foundation.

Hoyles, C., Wolf, C., Molyneux-Hodgson, S., Kent, P. (2002). Mathematical skills in the workplace. Final Report to the Science, Technology and Mathematics Council. London: University of London and Science, Technology and Mathematics Council.

Lester, W.F., Williams, V.J. (2010). Interactive investor education: an exploratory impact study in non-traditional learning environments. Business Education Innovation Journal, 2, 44-52.

Leuven E., Lindahl, M., Oosterbeek, H., Webbink, D. (2004). The effect of extra funding for disadvantaged pupils on achievement. IZA Discussion Paper No. 1122.

Lusardi, A., Mitchell, O.S. (2009). How ordinary consumers make complex economic decisions: financial literacy and retirement readiness. Working Paper 15350. National Bureau of Economic Research.

Lusardi, A., Tuffano, P. (2009). Debt literacy, financial experiences and overindebtedness. NBER Working Paper No. 14808.

Mandell, L. (2008). In overcoming the saving slump: how to increase the effectiveness of financial education and saving programs. Financial Literacy in High School, 20, 257-279.

Martin, F.S., (2007). A literature review on the effectiveness of financial education. Working Paper 07-03. Federal Reserve Bank of Richmond.

Mishkin, F.S. (2008). The importance of economic education and financial literacy. Speech before the Federal Reserve Board at the Third National Summit on Economic and Financial Literacy. Washington, DC.

OECD (2005). Recommendation on principles and good practices for financial education and awareness. OECD. Directorate for Financial and Entreprise Affairs.

OECD, (2014). PISA 2012. Technical Report. Available at: http://www.oecd.org/pisa/pisaproducts/PISA-2012-technical-report-final.pdf

Pinto, M.B, Mansfield, P.M., Parente, D.H. (2005). Information learned from socialization agents: its relationship to credit card use. Family and Consumer Sciences Research Journal, 33, 357-367.

Sajaia, X. (2008). Maximum likelihood estimation of a bivariate ordered probit model: implementation and Monte Carlo simulations. The Stata Journal 3(2), 311-328.

Samkin, G., Low, M., Taylor, J. (2012). Incorporating financial literacy into the secondary high school accounting curriculum: a New Zealand perspective. Australasian Accounting Business and Financial Journal, 6, 5-30.

Suiter, M. & McCorkle, S. (2008). Money math: Lessons for life. Center for Entrepreneurship and Economic Education. University of Missouri. Available at: https://www.treasurydirect.gov/indiv/tools/tools_moneymathintro.pdf.

Van Rooij, M.A., Lusardi, A., Alessie, R. (2011). Financial literacy and stock market participation. Journal of Financial Economics, 110, 449-472.

Varcoe, K., Martin, A., Devitto, Z., Go, C. (2005). Using a financial education curriculum for teens. Financial Counseling and Planning, 16, 63-71.

Williams, S. (2010). Parental influence on the financial literacy of their school-aged children: an exploratory study. Exceptional Children, Journal of Special Education, I, 23-33

Chapter 3

Are Secondary School Students from the Middle East Independent Learners?

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Abstract: Several factors influence the quality of higher education, inputs such as quality of students and teachers, the curriculum and the pedagogy. The purpose of our research was to examine whether there were any differences in learner autonomy as measured by self-directed learning readiness (SDLR) between secondary school students who entered medicine with a local Bahraini school certificate and those students who entered with an international school certificate. Using a modified questionnaire we identified how elements such as self-management, desire for learning, self-control and total SDLR scores varied in relation to the student's previous exit award: 'A' levels (or equivalent) or Bahrain Secondary School (BSS) certificate. BSS certificate students had a significantly lower mean standardised desire for learning score (63.5) compared to those entering with 'A' levels or equivalent (73.6; p=0.003). BSS certificate students also had a significantly lower mean total self-directed learning readiness score (192.3) compared to those students with the 'A' levels and equivalent (214.5; p=0.015). When we controlled for all the other factors, secondary school award certificate was the only independent predictor of self-control (standardised beta 0.4; p=0.02) and SDLR (standardised beta 0.36; p=0.043). Social shifts and changing economic workforce requirements both regionally and globally are driving an increased interest in higher education in the Middle East. Students who exit with a local secondary school certificate are finding it difficult to prepare themselves for independent learning in medical school. This poses a challenge for higher education institutions bringing a more learner autonomous type of curriculum to the Middle East.

Keywords: Self-directed learning; tertiary education; secondary school; medical student; culture; Middle East

Introduction

Higher education in the Middle East

The Middle East is a loose term, not always used to describe the same territory. It usually includes the Arab countries from Egypt east to the Persian Gulf, plus Israel and Iran. Middle East for the purposes of our study contains a number of Arab countries including Bahrain each with their own economic, political and social systems. Throughout history and societies of the Arab countries, higher learning has been deeply rooted and its people have placed a high value on education at all levels.

An essential goal of most Middle Eastern families being to achieve the best possible education for their children.

Public or state universities were established in the 1960s after the Gulf Cooperation Council countries had secured their own independence. These institutions were prone to producing poor results and suffered a lack of resources and training opportunities for staff (Wilkens & Masri, 2011). This lack of innovation in teaching and learning provided the impetus during the 1990s to shift favour from public institutions to private universities, but these latter institutions progress in improving performance of students was also negligible (Romani, 2009).

In 2003, the United Nations Development Programme published its second report on Arab Human Development, criticising the poor state of higher education throughout the region and urged Arab states to invest heavily in this sector (Fergany, El Hamed, & Hunaidi, 2002). A second report almost ten years later in 2011, describing higher education reform in the Arab world by the U.S. – Islamic World Forum reported that more than 80% of all universities in Bahrain, Lebanon, Palestine, Qatar and UAE were from the private sector (Klugman, 2011). Nonetheless, public sector institutions continue to serve the majority of the population throughout the region, but with overcrowding and shortage of resources it makes it more difficult to place the emphasis on the key ingredients of quality teaching, pedagogy, faculty and curriculum.

Social shifts and changing economic workforce requirements both regionally and globally are driving an increased interest in higher education in the Middle East. There are currently 1,239 Universities listed with over 50 of them being branch campuses. Bringing a more Western type of higher education to this region is the main aim of many international institutions with plans for global expansion. A good example of this are the countries of United Arab Emirates and Qatar who have established forty foreign branch campuses of Western universities over the last 10 years. But there are obviously challenges to bringing Western way of teaching and learning into the Arab Gulf region.

Secondary to tertiary learning in Middle East

Several factors influence the quality of higher education, inputs such as quality of student, teachers, curriculum and pedagogy. The academic preparedness of the graduates of secondary school represents an important factor for higher education success. The continuing emphasis at the secondary level of rote memorisation rather than focussing on techniques such as critical thinking has contributed to a pool of applicants that are underprepared for higher level tertiary learning (Wilkens & Masri, 2011). Students lack the requisite abilities of being analytical and autonomous learners, skills needed to study effectively at the tertiary level, this being an issue in many countries in the Middle East. Higher education does not take place in vacuum. Linkages between secondary and tertiary institutions are of paramount importance to improve the quality of the university entrant.

Self-directed learning

Promoting life-long learning amongst health professionals has been the main aim of a radical shake-up of medical education (Jackson & Calman, 2006). Students have to move from the memorisation of facts to problem-solving and self-directed study, these two skills have found to be necessary for the practice of medicine (Barrows, 1983). Modern medical curricula have also been transformed in moving from a passive, didactic teacher-dominated approach to a more student-centred, active, self-directed learning one (Shin, Haynes, & Johnston, 1993). The focus has been to develop future doctors who are less responding to instruction and taking more responsibility of their own learning. The importance of self-directed learning cannot be overstated; some authors have gone as far as suggesting that neglecting the development of self-directed learning is considered a serious disadvantage for the student learner (Kek & Huijser, 2009). Part of their life-long learning process involves the need for students to adopt self-directed learning readiness often described as the process of deciding what to learn, and to what depth and breadth (Candy, 1991). Others have defined the concept of learning readiness as the degree to which the individual possesses the attitudes, abilities and traits necessary for self-directed learning (Wiley, 1983). The study of self-direction has been explored primarily from two perspectives: either by the process (Brockett & Hiemstra, 1991) exemplified by the Personal Responsibility Orientation Model (Brockett & Hiemstra, 1991) or from personal attributes as described in Garrison's Three-Dimensional Model, (Garrison, 1997). Personal attributes such as desire for learning, self-control and self-management. Several models have been put forward to understand self-directed learning and focus on either process or attributes (Song & Hill, 2007).

The impact of culture on higher education

The globalisation of medical education has been rapid and intensive with very few medical schools escaping the effect (Jippes & Majoor, 2011). This ability of self-directed learning readiness may become one of the most important traits learners must have to survive, succeed and improve on their own (Guglielmino & Roberts, 1992). When it comes to self-directed learning readiness, one thing that is widely agreed upon is the need for more research to explore how culture impacts on self-directed learning readiness in students outside of North America and Europe in this world of globalised medical education (Gukas, 2007).

Frambach and colleagues explored the effect of culture on self-directed learning by examining three medical schools situated in Europe, the Middle East and East Asia. They concluded that uncertainty, tradition and hierarchy impacted on self-directed learning, thus impeding the uptake of the new learning approach by non-Western students but over time these two groups adapted to their learning environments (Frambach *et al.*, 2012). Only a handful of studies have gone on to explore the cultural impact on the preparedness of students for self-directed learning, Ahmad and Majid's appraisal was one such study. They examined the influence of Malay culture on self-directed learning among adult learners. Their study showed that culture can strongly influence the development of self-directed learning readiness (Ahmad & Majid, 2010). A second study done with South Korean and American college students examined the relationship between self-directed learning readiness and cultural values between the two groups of students. Their findings coincided with those of Braman (Braman, 1998) showing that self-directed learning readiness had a strong relationship with individualism (Lee & Lindner, 2005). Most cultural studies describe the notion of moving students from being spoon-fed to becoming a more autonomous andragogical learner, someone who takes responsibility for meeting their own learning needs (Fisher, King & Tague, 2001).

Defining culture is difficult with many explanations being put forward. Triandis attempted to define culture as, "functions to improve the adaptation of members of the same culture to a particular ecology, and includes the knowledge that people need to have in order to function effectively in their social environment (Triandis, 2000). Others have used societal terms to define culture such as ‘the glue that hold its members together through a common language, food, religion, beliefs, aspirations and challenges” (Abdullah, 1996). Whatever the definitive explanation, we can categorise cultural identity broadly as either collectivist or individualist. In a collectivist society members do not speak up, or even express a contradictory point (Beamer & Varner, 2008). In an individualistic culture, individuals organise themselves into loosely affiliated societies, primarily taking care of themselves and their immediate family (Hofstede, 2001). An important difference between collectivist and individualist cultures is the relative importance each places on the goals of the individual compared to the goals of the group (Braman, 1998). Children from collectivist cultures such as those living in the Middle East are situated in an environment which revolves around obedience, reliability, duty, cleanliness and order (Triandis, 2004). Taking charge of their own learning poses a major challenge to the majority of students entering tertiary education in the Arabian Gulf region (Al-Saadi, 2011a). Grow, 1991 explains that educational practices in public school and universities in the region, do more to perpetuate dependency than to create self-direction (Grow, 1991). This practice is further emphasised by a recent report describing the “spoon-feeding learning model” practiced by students and teachers in Oman (Al-Saadi, 2011b). Al-Saadi argues that learning becomes more effective when learners are in control of their learning and aware of the learning process and of themselves as learners.

The major goal of any tertiary institution should be to provide students with the necessary competencies to become lifelong learners, to bridge the gap between secondary and tertiary education. This is the emphasis of work done by Patterson and his colleagues in Canada with nursing students (Patterson, Crooks, & Lunyk-Child, 2002). They proposed six competencies required for students to become self-directed learners.

Research question and objectives

The objective of this study was to identify any differences in self-directed readiness between students who entered our medicine programme with a local Bahraini school certificate and those students who entered with an international school certificate. This study forms part of a larger study which introduced an intervention to enhance self-directed learning readiness (SDLR) in students regardless of their educational backgrounds.

Methods

Setting

Our study was conducted on the branch campus of the Royal College of Surgeons in Ireland (RCSI-Bahrain) situated in Bahrain; an international university which delivers an Irish five-year undergraduate medical curriculum to students from all over the world with local Bahraini students making 40% of the overall cohort. The students varied in their ethnic background and their approaches to learning, amongst other things.

In the first year the cohort was composed of three distinct categories of students. The first category consisted of those who have directly entered the programme by either having appropriate ‘A’ level qualifications or equivalent (International Baccalaureate or High School Diploma). The second category was composed of students entering through the Foundation Year (Foundation Year is our premedicine programme, which students have to successfully pass before they can move into the five-year programme) with a Bahrain Secondary School (BSS) certificate. The third category consisted of those students who already had a university degree.

Study design

In a cross-sectional study, we explored self-directed readiness amongst our first year medical students before they had undertaken any scheduled classes at the institution. Ethical permission was sought and obtained from the RCSI-Bahrain Research Ethics Committee. In the first week, of the first semester, students were given a brief overview of the study and invited to participate and if they agreed, written consent was obtained. Paper copies of the self-evaluation tool were then distributed to student who had consented, and they were asked to complete the questionnaire.

Participants

All 150 students' first year medical students in semester one were invited to participate in the study. From the first year cohort 65 students responded and completed the questionnaire (response rate 43%). The inclusion criterion was set to include those students with a BSSC or 'A' levels or equivalent who directly entered the programme or who came through the Foundation Year (50 students were included). Students who were excluded from the study were those entering the programme who possessed a Higher Education exit award or repeating students (15 students were excluded).

Tool

The learning readiness of undergraduate medical students was determined using a scale originally devised by Fisher and his colleagues (Fisher *et al.*, 2001) and later used to assess learning readiness amongst physiology students (Abraham *et al.*, 2011). The SDLR questionnaire is a self-evaluation tool determining the SDLR of an individual student. Our questionnaire was a modification of one previously used by Fisher with nursing students (Fisher *et al.*, 2001). The questionnaire was divided into three subcategories namely: self-management (9 items); desire for learning (13 items); self-control (11 items), giving a total of 33 items. Students were requested to respond to each item on a Likert scale (where 5=always, 4=often, 3=sometimes, 2=seldom, 1=never). The scale gave us the opportunity to calculate their subcategory scores as well as their total self-directed learning readiness score. All items were scored in a forward manner and no reverse manner questions were posed.

The validity of the modified questionnaire was determined by content validity (exploring pertinent literature) and face validity (experts' opinion on the modified questionnaire). The reliability of the internal consistency was determined by calculating Cronbach's alpha for self-management (0.7), desire for learning (0.8) and self-control (0.76) as well as the overall value for self-directed learning readiness (0.9).

Data management

We calculated the total for each subcategory (self-management, desire for learning and self-control) by adding the scores of each item in that subcategory. The total scores were then standardized out of 100 by dividing the total score by the maximum score possible in that subcategory and multiplying by one hundred. For example, in the self-management scale there are 9 items with each item having a maximum score of 5 and so actual student score was divided by 45 and multiplied by 100 to provide a standardized subcategory score out of a 100. The three subcategory scores were then added together to produce the standardized self-directed learning readiness total out of three hundred.

Statistical analysis

The data obtained from the questionnaire were entered, cleaned and prepared for analysis using IBM SPSS Statistics for Windows (IBM Corp., Armonk, NY, USA); data were summarised and presented using appropriate statistics: mean (standard deviation) and frequency (percentage) for numerical and categorical variables respectively. Differences of SDLR and its three subcategories (self-management, desire for learning and self-control) in relation to students' characteristics were compared using independent student's t-test and 95% confidence intervals (95% CI) for the means. All statistical tests were two-sided. A Type I error rate of $p \leq 0.05$ was used for statistical significance. Furthermore, to address our primary research question, a multivariate regression analysis was performed to see the net effects of each of the students' characteristics (independent variables) in explaining variation in SDLR and its three subcategories.

Results and Discussion

Participants' characteristics

The majority of the participants were female (66%). The predominant age group of students was less than 20 years (56%). The students that left school with a Bahrain Secondary School Certificate made up of 28% of the respondents. Those entering from the RCSI-Bahrain Foundation Year course made up the largest proportion of students entering the Junior Cycle (58%). The majority of the students were residents of the Middle East (86%) and the remainders were residents in Asia. Table 1 summarises the general characteristics of the participants.

Table 1. General characteristics of the participants

Main group	Sub-group	Frequency	Percent
Age groups	< 20 years	28	56
	20 years or more	22	44
Gender	Male	17	34
	Female	33	66
Secondary school award	Bahrain Secondary School Certificate	14	28
	IB and A levels	36	72
Country of residence of student	Middle Eastern	43	86
	Asian	7	14
Type of entry into Junior Cycle	Foundation Year	29	58
	Direct Entry	21	42

Descriptive statistics

Analysis of data revealed large differences between the maximum and minimum values for each subcategory, self-management (35.5, 88.9), desire for learning (40, 90.77), self-control (43.6, 90.9) and the overall SDLR score (126.9, 260.8). However, the mean scores (SD) for self-management was 68.6 (11.4), for desire for learning was 70.8 (11.2), for self-control was 68.9 (10.7), and for self-directed learning readiness was 208.3 (29.4). The descriptive statistics of the subcategories and the total SDLR are shown in Table 2.

Table 2. Descriptive statistics of the three subcategories and combined SDLR score of the participants

Statistics	Self-management	Desire for learning	Self-control	SDLR
Mean	68.6	70.8	68.9	208.3
Std. Error of Mean	1.6	1.6	1.5	4.2
Median	71.1	72.3	70	207.7
Std. Deviation	11.4	11.2	10.7	29.4
Minimum	35.6	40	43.6	126.9
Maximum	88.9	90.77	90.9	260.8

Determinants of SDLR

The univariate results are shown in Table 3, indicating the mean difference between the two groups with 95% confidence interval as well as the p value.

When the total SDLR scores and the three subcategories were compared among different age groups there was little difference between those students who were less than 20-years-old and those who were older. Country of residence also had no impact on any of the three subcategories and neither did type of entry into the Junior Cycle.

Where there was a statistically significant difference it was between male and females students desire for learning, with male students having a higher desire for learning score (75.6) than females (68.3; 95% CI of the Difference: 0.8 to 13.7, p value: 0.029). The largest difference was found between students who had entered with a local Bahrain Secondary School Certificate and those students who were admitted with ‘A’ levels or an equivalent such as an IB or High School Diploma.

Students with IB and ‘A’ levels tended to a higher more desire for learning score (73.6) compared to students with BSSC (63.5) (95% CI of the Difference -16.6 to -3.6, p value 0.003). They also tended to have greater self-control (71.2) compared to students with BSSC (63.1) (95% CI of the Difference -15.8 to -0.4, p value 0.04).

The differences between the total SDLR scores amongst these two groups were also significantly higher among students with IB and ‘A’ levels (214.5) than students with BSSC (192.3) (95% CI of the Difference -39.8 to -4.5, p value=0.015).

Table 3. Mean differences between the two groups of participants

		SM	DFL	SC	SDL
Age groups	< 20 years	68.4	73.1	68.3	209.8
	20 years or more	68.8	67.9	69.8	206.4
	Mean Difference	-0.4	5.2	-1.4	3.4
	95% CI of the Difference	-7 to 6.2	-1.1 to 11.5	-7.6 to 4.8	-13.6 to 20.3
	P value	0.91	0.1	0.64	0.69
Gender	Male	69.5	75.6	70.5	215.6
	Female	68.1	68.3	68.2	204.6
	Mean Difference	1.5	7.2	2.3	11.0
	95% CI of the Difference	-5.5 to 8.4	0.8 to 13.7	-4.2 to 8.8	-6.5 to 28.5
	P value	0.673	0.029	0.474	0.213
Secondary school award	BSSC	65.7	63.5	63.1	192.3
	IB and A levels	69.7	73.6	71.2	214.5
	Mean Difference	-4.0	-10.1	-8.1	-22.2
	95% CI of the Difference	-11.2 to 3.2	-16.6 to -3.6	-15.8 to -0.4	-39.8 to -4.5
	P value	0.27	0.003	0.04	0.015
Country of residence of student	Middle Eastern	68.6	71.0	69.0	208.7
	Asian	68.3	69.5	68.6	206.3
	Mean Difference	0.4	1.6	0.4	2.4
	95% CI of the Difference	-9.1 to 9.8	-7.7 to 10.8	-8.5 to 9.3	-22 to 26.7
	P value	0.94	0.73	0.92	0.85
Type of entry in to Junior Cycle	Foundation Year	69.5	68.4	67.8	205.7
	Direct Entry	67.3	74.1	70.6	212.0
	Mean Difference	2.2	-5.8	-2.8	-6.3
	95% CI of the Difference	-4.4 to 8.8	-12 to 0.5	-9 to 3.4	-23.3 to 10.7
	P value	0.51	0.071	0.37	0.46

Predicting factors which affect SDLR

Table 4 shows the multivariate regression analysis which allowed us to explore the net effects of each of the students' characteristics (independent variables) in explaining variation in SDLR and the three subcategories. When we controlled for all other factors, secondary school certificate was the only independent predictor of the self-control (Standardized beta 0.4, p=0.02) along with SDLR (Standardized beta 0.36, p value=0.043).

Table 4. Results of Multivariate Regression Analysis

	SM		DFL		SC		SDL	
	Beta	P value	Beta	P value	Beta	P value	Beta	P value
Age groups	-0.06	0.77	-0.06	0.737	0.33	0.087	0.07	0.707
Gender	0.00	0.987	-0.15	0.331	0.05	0.732	-0.04	0.820
Secondary school award	0.25	0.171	0.30	0.07	0.40	0.02	0.36	0.043
Country of residence	-0.02	0.873	-0.02	0.874	-0.07	0.629	-0.04	0.769
Type of entry into Junior Cycle	-0.25	0.24	0.04	0.828	0.18	0.353	-0.01	0.946
Constant	69.45	0	65.89	0.000	39.43	0.017	174.77	0.000
R Square	0.062		0.198		0.178		0.125	

Self-direction has been described as an outcome of cumulative effects on learning resulting from progressive development of student responsibility for learning (Miflin, Campbell, & Price, 2000). This study set out to examine whether there were any differences in SDLR amongst students who entered the medicine programme from the local Bahraini secondary schools and those students who exited secondary schools with 'A' levels or equivalent awards. We found that there were indeed statistically significant differences between these students especially in the desire for learning and self-control subcategories. Our results plainly indicate that students who have exited from a local school with a secondary school certificate were not prepared in any of the subdomains of self-learning readiness: self-management, desire for learning and self-control, with the last two subcategories being statistically significant. These domains were described in full in William's study conducted in 2012 (Williams *et al.*, 2012). But in brief, the self-control subcategory determines the student's ability to self-evaluate. The self-management subcategory determines the student's ability to implement their own learning goals and manage the resources available to them.

There were no significant differences between SDLR scores when comparing age of the students this result correlates with the other studies done, one in Saudi Arabia with nursing students (El-Gilany & Abusaad, 2013) and a second done in Taiwan (Chen, Wang & Lin, 2006). We did however find a significant difference when comparing scores between males and females, with the former having higher scores in the desire for learning subcategory. This category focussed on the student's motivation for learning and their ability to reflect on their motivation. Gender has been found to play an important role in the same subcategory in a self-directed learning study conducted on paramedic undergraduate students (Williams *et al.*, 2012). However, the biggest difference and the single predictive factor in our study was found to be secondary school exit award, those students who left with a local Bahraini secondary school certificate had lower scores for all three subcategories of self-directed learning readiness.

Culture has been shown to play an important role in adult learning (Brookfield, 1980). Our local students are nurtured in a collectivist culture where the emphasis is on social harmony. This cultural influence does not encourage the development of traits such as motivation and readiness to accept responsibility essential for the successful self-directed learner (Garrison, 1992). A study done with Malaysian students, another good example of a collectivist culture, identified that these students struggled with the development of learner autonomy (Ahmad & Majid, 2010). Such a conflict often arises in the minds of such students when adhering to their cultural values while attempting to promote their learning by developing their individualism, which is described much more explicitly by Knowles as 'a process in which the individual takes the initiative, with or without the help of others' (Knowles, 1975). This lack of learner autonomy is not new, studies have described the challenges in adopting such a model for University students in other countries in the Middle East such as Oman. These include teacher's lack of understanding about learner autonomy, lack of resources to adopt learner autonomy and community expectations of both the educational institution and the teacher (Al-Saadi, 2011b). Other studies have shown this obvious tension in moving from collectivist beliefs which are rooted in the norms, obligations and duty to more autonomous individuals (Hwang, Francesco, & Kessler, 2003).

Learner autonomy is a central dimension of independent learning (Moore, 1972) and programmes in which autonomy is fostered should be encouraged (Thanasoulas, 2000). Students from the local schools are struggling to develop this autonomy due to the passive learning process adopted in most regional secondary schools. A similar type of passive learning which exists in Middle Eastern schools was described in a study conducted at a Nepalese medical school where rote learning and reproduction of factual information dominated in their local schools (Shankar *et al.*, 2011). The importance of supporting autonomy in medical education is clearly laid out by Williams and his colleague in an article published in the late 90s. In which they argue that students who learn autonomously, freely choose to read and study because they find material interesting or important to their identity as a physician (Williams & Deci, 1998). However, in Middle Eastern countries such as Oman, learner independence is not held in high-regard in secondary education and spoon-feeding of information to students is prevalent in local schools. Pupils have no say on what to study and how to study, and skills such as metacognition and reflection are being largely excluded from the curriculum (Al-Saadi, 2011a). For students to take charge of their own learning poses a major challenge for the majority of students entering tertiary education in the Arabian Gulf region (Al-Saadi, 2011b). This is reflected in our own findings where we show a statistically significant difference in the SDLR self-control subgroup between local school students scoring 63.1 out 100 and those taught based on the British school system attaining 'A' levels who scored 71.2 out of 100, p value 0.04.

While the pool of university students eager to enter the tertiary education system is ever increasing, many of these students do not meet admission entry criteria or are underprepared for independent learning. This disconnect between the secondary and tertiary education in the Middle East has been reported elsewhere (Rupp, 2009) and has led us and other Western-style higher education institutions to develop a number of pedagogical approaches to build and improve learner autonomy amongst our local entrants (Mills, 2008). Such supportive programmes help students prepare for the rigour of a Western curriculum by introducing a year-long remedial programme. In order to correct this disconnect at our own institution, our medical school has developed a premedicine programme termed Foundation Year which allows students to improve and build their knowledge of English and Science in order to help them make a smoother transition into the five year medicine programme. This programme introduces a number of pedagogical methods which allows students, especially local students to build their learner independence. Our results show that the Foundation Year students who participated in this study did not appear to have developed sufficient learner autonomy. This gives us the impetus to adjust the Foundation Year curriculum in such a manner as to try and incorporate more explicit methods to help students develop their learner independence.

Grow suggests that teachers can actively equip students to become more self-directed in their learning and even suggesting a model to assist teachers (Grow, 1991). Projects at our institution where learner independence has been explicit have been much more successful and were based around a series of practicals to learn human anatomy.We have developed in-house programmes where the emphasis has been on learning information in a self-directed manner. These projects have been quite successful and are based around a series of practicals designed to teach human anatomy. For each practical class the activities were divided into three sets of tasks which were described in detail in a dedicated guide available as part of our online teaching resources. The first set of tasks was to be completed before coming to class. For this part of the exercise, students in their own time attended a delicated study room which was equipped with a series of anatomical teaching models (Somso®, Germany) which provided them with the necessary background information appropriate to the scheduled practical (Moravec, Williams, Aguilar-Roca, & O'Dowd, 2010). They were free to undertake this work on their own, or collaboratively in small groups. The material had to be covered in advance of the scheduled practical which constituted the second set of tasks. These involved a further series of anatomical teaching models (Somso®, Germany) which were studied during the class and these tasks involved the active participation of teachers who acted as facilitators during the session. The third and final set of tasks was to be completed after the scheduled practical sessions. They required the students either to work on their own or form small discussion groups (Jones, 2007) (Chiriac, 2014) in their own time and work through a number of exercises which included the analysis of carefully-selected case histories and specific questions designed to maximise the benefit they obtained from this activity. The whole process allowed the students take charge and develop their own learning in a self-directed manner. The benefit was evident from the improvement in their self-directed learning readiness scores.

The limitations of the study were that the data were collected on a self-reporting basis which could be subject to recall bias. Additionally, the small unequal sample size among the two groups could have contributed to some of the observed differences. A further limitation was that the results were from a cross-sectional study and not a longitudinal one. This was something we were aware of and we conducted a follow-up with the same questionnaire at the end of the first semester, thirteen weeks after we had introduced the self-directed learning classes in human anatomy. These results showed no significant differences between local school students and those exiting with

'A' levels or equivalents in any of the three subcategories or in the total self-directed learning score.

Integrating unprepared secondary school students into modern Western medical curricula remains an interesting challenge for those of us engaged in in higher education teachingn. Whilst students struggle to adopt individualistic traits in order cope with learner independence, teachers working in international higher education institutions should devise strategies to expedite the introduction of approaches that will help local students cope with a more Western curricula. The pressure on students is great and to ease their transition from secondary to tertiary education we as teachers should squarely place an emphasis on self-directed learning as a learning strategy for formal undergraduate studies and beyond into for life-long learning.

Conclusions

Self-directed learning is a key skill in the modern medical curriculum. Students who exit with a local secondary school certificate seem unprepared for this type of new learning strategy. This creates an educational challenge for institutions bringing a more modern curriculum with a focus on learner autonomy to the Middle East. Consideration must therefore be given to the development of more appropriate methods to assist such students in adopting this approach to learning in tertiary education.

Some recommendations include:

1. To realign the secondary school curriculum in order to adjust for the mismatch between secondary and tertiary education
2. Make an adaptation to introduce skills in the preparatory year of the tertiary degree level to improve the transition
3. An opportunity is created for private sector to produce short courses to help bridge the gap for autonomous students

Any future research should focus on the two key areas to enhance the transition for students from secondary to tertiary education.

1. Identifying implementation challenges
2. Designing innovative methods to introduce more autonomous learner opportunities

References

Abdullah, A. (1996). *Going glocal: Cultural dimensions in Malaysian management*: Malaysian Institute of Management.

Abraham, R. R., Fisher, M., Kamath, A., Izzati, T. A., Nabila, S., & Atikah, N. N. (2011). Exploring first-year undergraduate medical students' self-directed learning readiness to physiology. *Advances in Physiology Education, 35*(4), 393-395. doi: DOI 10.1152/advan.00011.2011.

Ahmad, B. E., & Majid, F. A. (2010). Self-directed learning and culture: A study on Malay adult learners. *Procedia-Social and Behavioral Sciences, 7*, 254-263.

Al-Saadi, H. M. (2011a). [From spoon-feeding to self feeding: helping learners take control of their own learning.]. 3.

Al-Saadi, H. M. (2011b). Towards a pedagogy for autonomy in language education in Oman. Unpublished paper.

Barrows, H. S. (1983). Problem-based, self-directed learning. *JAMA, 250*(22), 3077-3080.

Beamer, L. & Varner, I. I. (2008). *Intercultural communication in the global workplace*: McGraw-Hill Boston, MA.

Braman, O. R. (1998). *The cultural dimension of individualism and collectivism as a factor in adult self-directed learning readiness.* (1998 Dissertation). Retrieved from http://aquila.usm.edu/theses_dissertations/1806.

Brockett, R. G. & Hiemstra, R. (1991). *Self-Direction in Adult Learning: Perspectives on Theory, Research, and Practice. Routledge Series on Theory and Practice of Adult Education in North America*: ERIC.

Brookfield, S. D. (1980) *Independent adult learning. [electronic resource]*. University of Leicester.

Candy, P. C. (1991). Self-direction for lifelong learning: a comprehensive guide to theory and practice. San Francisco: Jossey-Bass.

Chen, Y.-F., Wang, C.-M., & Lin, H.-J. (2006). Explore the relationships among demography, personality traits and self-directed learning. *The Journal, 141*.

Chiriac, E. H. (2014). Group work as an incentive for learning–students' experiences of group work. *Frontiers in psychology, 5*.

El-Gilany, A.-H. & Abusaad, F. E. S. (2013). Self-directed learning readiness and learning styles among Saudi undergraduate nursing students. *Nurse Education Today, 33*(9), 1040-1044.

Fergany, N., El Hamed, A., & Hunaidi, R. (2002). Arab Human Development Report 2002: Creating Opportunities for Future Generations. *Cairo: Government of Egypt, Institute of National Planning*.

Fisher, M., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse education today, 21*(7), 516-525.

Frambach, J. M., Driessen, E. W., Chan, L. C., & van der Vleuten, C. P. (2012). Rethinking the globalisation of problem-based learning: how culture challenges self-directed learning. *Medical education, 46*(8), 738-747.

Garrison, D. (1997). Self-directed learning: Toward a comprehensive model. *Adult Education Quarterly, 48*(1), 18-33.

Garrison, D. R. (1992). Critical Thinking and Self-Directed Learning in Adult Education: An Analysis of Responsibility and Control Issues. *Adult Education Quarterly, 42*(3), 136-148. doi: 10.1177/074171369204200302.

Grow, G. O. (1991). Teaching Learners To Be Self-Directed. *Adult Education Quarterly, 41*(3), 125-149. doi: 10.1177/0001848191041003001.

Guglielmino, P. J., & Roberts, D. G. (1992). A comparison of self-directed learning readiness in US and Hong Kong samples and the implications for job performance. *Human Resource Development Quarterly, 3*(3), 261-271.

Gukas, I. D. (2007). Global paradigm shift in medical education: issues of concern for Africa. *Med Teach, 29*(9), 887-892. doi: 10.1080/01421590701814286

Hofstede, G. H. (2001). *Culture's consequences: Comparing values, behaviors, institutions and organizations across nations*: Sage.

Hwang, A., Francesco, A. M., & Kessler, E. (2003). The relationship between individualism-collectivism, face, and feedback and learning processes in Hong Kong, Singapore, and the United States. *Journal of Cross-Cultural Psychology, 34*(1), 72-91.

Jackson, M. & Calman, K. (2006). Medical Education past, present and future. *Medical Education, 40*(3), 190-192.

Jippes, M. & Majoor, G. D. (2011). Influence of national culture on the adoption of integrated medical curricula. *Adv Health Sci Educ Theory Pract, 16*(1), 5-16. doi: 10.1007/s10459-010-9236-5.

Jones, R. (2007). Learning and teaching in small groups: characteristics, benefits, problems and approaches. *Anaesthesia and intensive care, 35*(4), 587.

Kek, M. Y. C. A. & Huijser, H. (2009). What makes a deep and self-directed learner: exploring factors that influence learning approaches and self-directed learning in a PBL context at a Malaysian private university. *Proceedings of the 2nd International Problem-based Learning Symposium (PBL 2009)*, 708-718.

Klugman, J. (2011). Human Development Report 2011. Sustainability and Equity: A Better Future for All. *Sustainability and Equity: A Better Future for All (November 2, 2011). UNDP-HDRO Human Development Reports*.

Knowles, M. S. (1975). *Self-directed Learning: A Guide for Learners and Teachers*: Association Press.

Lee, I. H., & Lindner, J. R. (2005). Readiness ofr self-directed learning and the cultural values of individualism and collectivism among Americans and South Korean college students seeking teacher certification in agriculture. . *Association for International Agriculture and Extension Education, 21*, 601- 611.

Miflin, B., Campbell, C., & Price, D. (2000). A conceptual framework to guide the development of self-directed, lifelong learning in problem-based medical curricula. *Medical Education, 34*, 299-306.

Mills, A. (2008). US Universities Negotiate Tricky Terrain in the Middle East. *Chronicle of Higher Education, 54*(46).

Moore, M. G. (1972). Learner autonomy: The second dimension of independent learning. *Convergence, 5*(2), 76-88.

Moravec, M., Williams, A., Aguilar-Roca, N., & O'Dowd, D. K. (2010). Learn before lecture: a strategy that improves learning outcomes in a large introductory biology class. *CBE-Life Sciences Education, 9*(4), 473-481.

Patterson, C., Crooks, D., & Lunyk-Child, O. (2002). A new perspective on competencies for self-directed learning. *Journal of Nursing Education, 41*(1), 25.

Romani, V. (2009). The politics of higher education in the Middle East: Problems and prospects. *Middle East Brief, 36*, 1-8.

Rupp, R. (2009). Higher education in the Middle East: Opportunities and challenges for US universities and Middle East partners. *Global Media Journal*.

Shankar, R., Bajracharya, O., Jha, N., Gurung, S. B., Ansari, S. R., & Thapa, H. S. (2011). Change in medical students' readiness for self-directed learning after a partially problem-based learning first year curriculum at the KIST medical college in Lalitpur, Nepal. *Educ Health (Abingdon), 24*(2), 552.

Shin, J. H., Haynes, R. B., & Johnston, M. E. (1993). Effect of problem-based, self-directed undergraduate education on life-long learning. *Cmaj, 148*(6), 969-976.

Song, L., & Hill, J. R. (2007). A conceptual model for understanding self-directed learning in online environments. *Journal of Interactive Online Learning, 6*(1), 27-42.

Thanasoulas, D. (2000). What is learner autonomy and how can it be fostered. *The Internet TESL Journal, 6*(11), 37-48.

Triandis, H. C. (2000). Culture and conflict. *International Journal of Psychology, 35*(2), 145-152.

Triandis, H. C. (2004). *Culture and Social Behavior*: McGraw Hill Custom Publishing.

Wiley, K. (1983). Effects of a self-directed learning project and preference for structure on self-directed learning readiness. *Nurs Res, 32*(3), 181-185.

Wilkens, K. A., & Masri, S. (2011). *Higher education reform in the Arab world*: Saban Center at Brookings.

Williams, B., Boyle, M., Winship, C., Brightwell, R., Devenish, S., & Munro, G. (2012). Examination of self-directed learning readiness of paramedic undergraduates: A multi-institutional study. *Journal of Nursing Education and Practice, 3*(2), p102.

Williams, G. C., & Deci, E. L. (1998). The importance of supporting autonomy in medical education. *Annals of internal medicine, 129*(4), 303-308.

Chapter 4

Engaging way to help students develop skills, interest and methodological research approaches in Marine and Environmental science

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Abstract: Learning in teamwork appeared to be a winning methodology for science education, as it enhances student's autonomy and strengthens their skills. The involvement of students in research activities is an example of this approach. Moreover, interaction between the scholastic and the research world can bring benefits for both: educational benefits for students in terms of "acquisition of competences", and the possibility, for researchers, to have help for data collection and analysis (citizen-science). Involving students as volunteers not only in data collection, but also in problem definition and data analysis, can be further engaging for them, stimulating interest for the treated argument. We describe two projects, carried on in the same geographical area, devoted to integrate marine science topics in high/middle school education. Students are engaged in real research activities, (inquiring-based learning) and this approach leads to a scientific follow-up in terms of growing knowledge of environmental parameters, as loss of biodiversity and pollution from marine litter. From the methodological point of view, didactic tools as peer education and emotion–based learning have been experimented with success, as indicated by an inquiry about "perception of science" carried on a group of students who participated in one of the two projects.

Keywords: Environment; marine-litter; biodiversity; citizen-science; peer-learning; education

Project contexts

Marine science and the territorial context

Marine sciences span a wide range of fields, from oceanography to coastal erosion, from environment to marine life, from studies in extreme places, as Arctic and Antarctic Sea, to the role of ocean in climatic changes. In this sense they are interdisciplinary; a study involves a basic understanding of chemistry, physics, geology, biology, ecology etc. Nevertheless, rarely in middle and high school curricula there is a mention of this type of study, and also at the University level only few courses are devoted to this particular field. During the last decade, The NMEA (National Marine Educators Association, http://www.marine-ed.org/, USA) Ocean Literacy Committee made repeated contributions at national level with the aim to create the Next Generation Science Standards (NGSS) to ensure marine and ocean subjects were included throughout. Moreover, the NMEA International Committee supports also global participation in marine education and the promotion of ocean literacy around the world, thanks to conference organization and publication of the specialized Journal "*Current: The Journal of Marine Education*". In Europe the correspondent Association (European Marine Science Education Association, EMSEA) was formed only very recently, during its first meeting in Plymouth, England, in 2013. Until now, no significant progress has been made towards the inclusion of the marine science subjects among scholastic topics.

On the other hand, especially in Italy - a country with an extensive coastline, many large islands and an economy historically and geographically tied to the sea - to teach marine science in schools could be a valid instrument to involve students for better knowing and preserving the places where they live.

Moreover, the presence of the sea in the proximity of many Italian towns could act as a stimulus for the design of experimental activities and practices in situ, i.e. activities that will surely involve students also from an emotional point of view, favoring interest and curiosity and increasing their learning ability (Damasio *et al.*, 1994, Bechara *et al.,* 2000, Guile *et al.*, 2001).

In this sense the Gulf of La Spezia looks like an ideal place, for different reasons. This gulf is one of the widest and deepest of the whole Tyrrhenian coast, enclosed between two headlands and bordered by an amphitheater of hills and mountains. To west, the Cinque Terre National Park (http://www.parconazionale5terre.it/), a World Heritage Site, is one of the most important and beautiful natural Mediterranean areas. Human activity has helped to create a unique landscape in which the total length of the typical stone walls reaches the length of the famous Great Wall of China. All these aspects, together with the characteristics of a crystalline sea and a great network of paths, made the Cinque Terre an increasingly popular destination for Italian and foreign tourists. Other important marine parks have been established in this area, as the Regional Park of Portovenere and Palmaria Island (http://www.parconaturaleportovenere.it/), and the Monte Marcello regional fluvial and marine park, located at the mouth of the Magra River, which sets up the border between the regions of Liguria and Tuscany.

On the other hand, all these areas are unfortunately located just at the border of highly industrialized zones, where an LNG (Liquid Natural Gas) terminal, a thermal power plant, a port that accommodates container ships of great tonnage and many industrial activities in the navigation field coexist. Moreover, other practiced activities are fishing, fish and mussel farming, end, in summer, a huge touristic flow. Therefore the considered areas are subject to intensive boat traffic, and consequently also biological invasions of new species, a daily and common treat for coastal communities that is often underestimated (Lodola *et al.*, 2012). Moreover, the presence of an increasing number of anthropogenic marine debris (AMD), especially plastic and polystyrene, is a serious problem that may also have implications for biological communities, and represents one of the negative consequence of our plastic age (Thomson *et al.*, 2009).

All this inevitably leads to big contrasts and significant environmental impacts. The presence of Marine Protected Areas (MPAs) and of the very important Pelagos Sanctuary of marine mammals (http://www.sanctuaire-pelagos.org/en/) should involve, for the local institutions, special attention to the environment and to the protection of these delicate ecosystems. Therefore, there should be a greater education and awareness of citizens and workers about the regulations regarding environmental protection. In reality this is not always the case, as demonstrated by the results of monitoring programs (Suaria & Aliani, 2014, Merlino *et al.,* 2015b), which show a massive presence of polystyrene and nets in areas battered by fishing vessels.

Scientific and didactic context

In these restricted area, 5 research centers dedicated to marine studies[2] are presents. This fact should be a further stimulus to create synergy between school and research in the same territorial context. Instead, as it often happens in the scientific world, the focus of research carried out in some of these centers is devoted to remote areas, such as the Arctic sea, the Antarctic sea, the Atlantic ocean or, also remaining in Italy, the Adriatic sea, and only very few projects regard the areas placed “just downstairs”. This fact, together with the absence of marine science topics in scholastic programs, has led people operating in different realities (both research and educational institutions) to start specific paths of “education in marine science”. The aim of those paths is to involve, as much as possible, the local student population (but also citizens and volunteer associations) in monitoring, through environmental surveys, the area belonging to Pelagos Sanctuary.

In particular two projects started during the scholastic year 2012-2013, one independently from the other, with this purpose. They present the same methodological characteristics, but deal with two different fields, inside marine science. The first is “Percorsi nel Blu/BluePaths”, born inside the Unified School District 2 Giugno of La Spezia, and deals with the monitoring of biocenosis of beaches and sublittoral zone, analyzing littoral flora and fauna from upper and middle shore. The second one was born within a research institute in marine science of the CNR (National Research Council), and deals with the estimation of quantity, typology, and accumulation rates[3] of *marine litter*, anthropogenic debris present in sea and on the beaches.

Both projects are born with the same purpose to engage students in experimental activities to be performed in the area where they live. This approach produces an increase of specific knowledge, fosters the rising of interest in environmental and scientific problems and, moreover, has a research fall-out, because students really help scientists in collecting data during the beach surveys [Hidalgo-Ruz & Thiel, 2013; Eastman *et al.* 2014].

In the next paragraphs, we should like to focus our attention more on the educational aspect of the presented projects, than on the scientific one, even if the two aspects are strongly linked for both projects.

[2] Institute of Marine Sciences of Italian Research Council (ISMAR-CNR), National Institute of Geophysics and Volcanology (INGV), Centro di Supporto e Sperimentazione Navale (CSSN) of Italian Navy, Centre for Maritime Research & experimentation (CMRE) of NATO Organization, and Marconi University Pole.

[3] Number of items (or weight or volume) of beached trash per unit surface of beach per unit of time.

Raising interest on Marine Science

As we said before, for both projects the adopted strategy to foster students interest for marine science is to propose them arguments that are particularly important, not only for the scientific community but also for the public opinion.

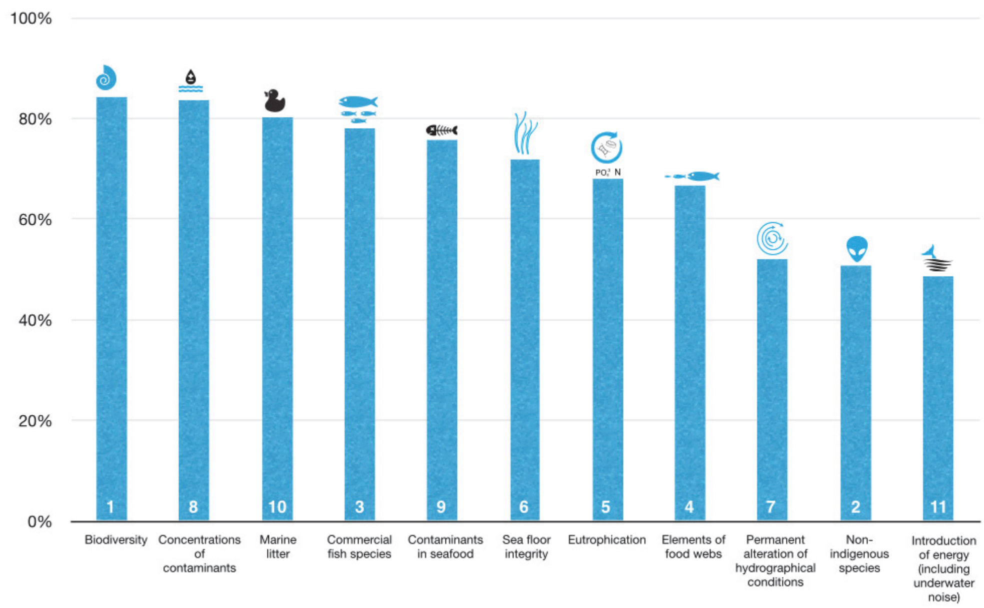

Figure 1. Results of public perception on relevance of the 11 Descriptors of the Marine Strategy Framework Directive in Italy. The results of this public consultation - carried out by ISPRA in 2014 - show a high evaluation and interest for Descriptors n.1 "Biodiversity", n.8 "Concentration of Contaminants" and n.10 "Marine Litter" (re-elaborated graph from ISPRA, 2014)

The identified topics should represent, for the learners, a challenge which stimulates them intellectually but also emotionally and socially.

In this sense the topics treated by the two projects BluePaths and SeaCleaner proved to be an excellent choice: both "biodiversity" and "marine litters" have been selected among the 11 descriptors that the Marine Strategy Framework Directive (MSFD, 2008/56/EC) define, in order to establishes the necessary measures to achieve or maintain good environmental status (GES) in the marine environment, by the year 2020 (Galgani *et al.*, 2013). Moreover, the latest public consultation carried out by ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale, 2014) showed that loss of Biodiversity (Descriptor n.1), and presence of Marine Litter (Descriptor n.3) - in the seas and in the coastal zones of the whole world - have been considered important and relevant issues. This consultation involved citizens and experts with questions concerning their opinion about the implementation of the MSFD and the best strategies to achieve the GES in the Italian seas **(Figure 1).**

The fact that the ISPRA consultation involved citizens to express their views concerning the marine litter problem clearly shows that these issues must be first fully understood not only by the Scientific Community but also by Citizens. The popular campaigns for beach cleanups such as Clean up the Med or Clean up Europe[4] (Legambiente, 2015), aren't enough powerful for raising awareness in this topic. Also citizens living near to these coastal areas aren't aware of the great impacts of man-made debris and trash, present especially during winter season, when coastal areas are literally covered by huge amounts of AMD coming from rivers, sea-currents and winds. The general perception of this problem is usually distorted because people mostly attend the beaches during summer season, when cleaning activities are carried out by municipalities or beach resorts. During summer only some off-limits areas (i.e. restricted MPAs) remain not clean (and often unclean!), but, in general, people haven't full access to these areas. The best way for raise awareness, instead, is to bring this problem in front of everybody!

Similarly, the issue of biodiversity has two aspects: one linked to the collection of a large number of data, and the other connected with the respect we should have for many marine species - both animal and vegetable - endangered or, otherwise, becoming increasingly rare in our coasts.

The problem of data collection requires the involvement and the commitment of a huge number of people since these issues should be understood after a deep analysis of long-term data series; this problem can be satisfied by citizen-scientists, i.e. volunteers participating in monitoring activities (Newman *et al.*, 2012; Cerrano *et al.*, 2013; Hidalgo-Ruz & Thiel, 2013; Thiel *et al.* 2014). Often motivating and enabling all these volunteers in a long-term commitment may represent a problem, and so our choice to involve students is particularly appropriate. These environmental problems are often unknown by students, and, as stressed before, not treated in standard scholastic programs: to raise awareness and to educate the younger generation about this issue, and to involve them in real monitoring programmes, leads to join the scientific/environmental value with the educational one.

The similarity in the adopted educational strategy of BluePaths and SeaCleaner, and the fact that the two important MSFD descriptors (biodiversity and marine litter) they are monitoring can be related one with the other, represented a strong push to create a synergy between the two projects. In fact, the presence on our coasts of an increasing number of anthropogenic marine debris (AMDs), especially plastic and polystyrene, is a serious problem that may also have implications for the biological communities, especially on marine mammals that are filter feeders (Fossi *et al.*, 2012; Cole *et al.*, 2013; 2015). From the scientific point of view, until now information are still very scarce on the Marine Litter problem in the North Tyrrhenian beaches and coasts as, for example, in the area of the Pelagos Sanctuary http://www.strategiamarina.isprambiente.it/sintesi-risultati-consultazione-2014).

Moreover, no sufficient studies have been carried on to establish clear relationships between Marine Litter density and possible effects on benthic communities. Hence, the need to conduct a biological monitoring repeated over time in order to register the presence of particular rare species, in the same area of the marine litter surveys, and the necessity to investigate the impact of plastics fragmentation on the marine ecosystem (Cole *et al.*, 2013; 2015).

[4] Clean Up the Med: http://www.festambiente.it/index.php/newsdett/items/801.html; Clean Up Europe: http://www.ewwr.eu/it/take_part/lets-clean-up-europe.

Sharing forces and building a network

Starting from these premises, Blue Paths and SeaCleaner started their collaboration in 2013, sharing methodologies, the monitored area and also creating occasions in which students of the two projects could interact each others, and interact, also, with volunteers of environmental organizations, researchers of other centers, university students etc. The purpose is to give to students the opportunities to approach the proposed arguments by different points of view, as the environmental one, the scientific one, the civic one etc.

It is largely recognized that being part of a network generates mutual expectations that feed back on the institutional arrangements, also by allowing for strategic alliances. For example, the series of Framework Programs of the European Union have increasingly focused on so-called Research, Technology, and Development (RTD) networks (Etzkowitz & Leydesdorff, 1997). Another example of winning network is the so-called Triple Helix (such as the Italian industrial clusters that have been widely desired because of their economic potential (Ferraro &Borroi, 1998). They can be considered as hyper-networks, and because of the multitude of formal and informal links between institutions involved in these networks, the niches can be maintained with extremely high problem-solving capacities (Biggiero, 1998).

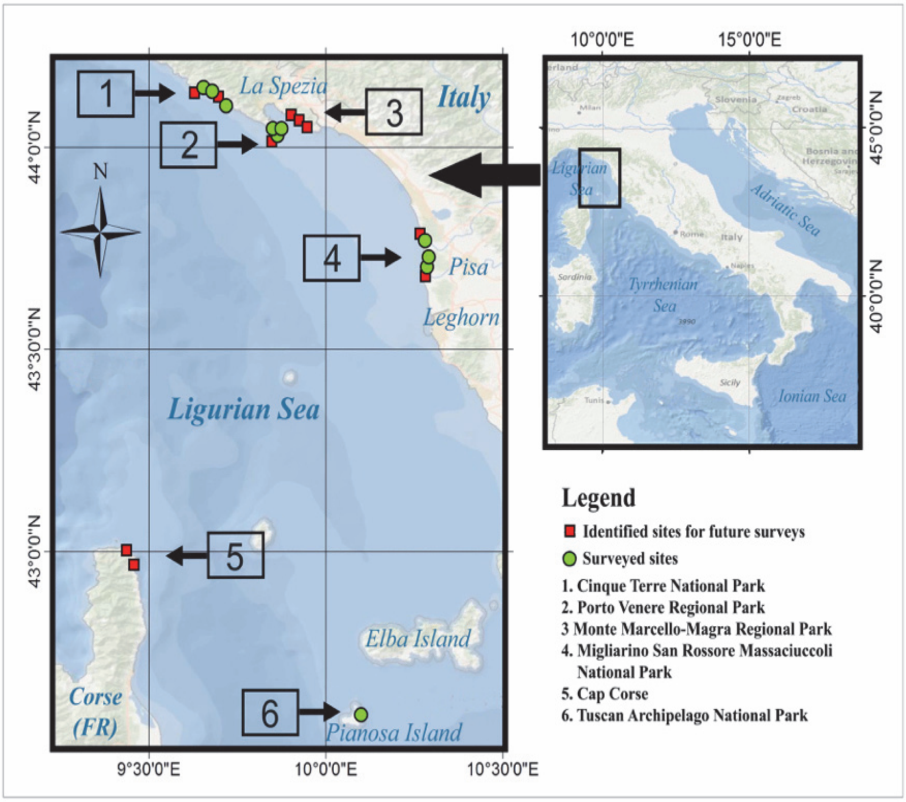

Figure 2. BluePaths ("Percorsi nel BLU") and SeaCleaner projects are presently cooperating and monitoring 5 areas of the Tuscan and Ligurian coasts plus one in France. The whole East Ligurian/North Tyrrhenian area - here indicated - is of great importance because it comprises the Pelagos Sanctuary (for marine mammals protection) and several coastal MPA (1: Cinque Terre National Park; 2: Portovenere and Palmaria Island Regional Park; 3: Montemarcello-Magra Regional Park; 4: Migliarino San Rossore Massaciuccoli Natural Park; 5: Tuscan Archipelago National Park)

So, in order to carry forward their monitoring programs, people working in BluePaths and SeaCleaner projects decided, as first step of their collaboration, to set up a network of partners. Given the environmental issues addressed in both projects, the created network involves: Research Institutes (the Institute of Marine Sciences of Italian Research Council, CNR-ISMAR and the National Institute of Geophysics and Volcanology, INGV); a Regional Cluster (Ligurian Cluster for Marine Technologies, DLTM) and 5 National and Regional parks surrounding the Pelagos Sanctuary (**Figure 2**).

But the real innovation of this network is the inclusion of scholastic institutes, both comprehensive institutes, i.e. Istituti Comprensivi (Documenti e Studi degli Annali della Pubblica Istruzione, 1998), as well as secondary (middle and high) schools, in order to start a concrete link between research and education; a link that, through instruments such as the peer and intergenerational learning and citizen science contribution (Newman *et al.*, 2012), brings benefits to both research and education (Osborne *et al.*, 2003; Catarsi &Ciardi 2010; Corona *et al.*, 2013).

For SeaCleaner project, collaboration with education institutions led, in the scholastic year 2013-2014, to the active involvement of 44 students of both middle and high school. The number of involved students has highly grown during the following scholastic year, arriving to 80 at the end of 2015 (for both middle and high school), with a parallel increase of the number of volunteers and environmental associations involved, in this case, in extracurricular activities (as the already quoted European campaigns for cleaning the beaches "Clean the Med", "Clean Up the Europe" etc.) Consequently, also the number of monitored sites had a significant increase [Merlino *et al.* 2015b].

BluePaths, that involves students - and their relatives and friends, together with volunteers - in biological surveys performed also out of the school hours, has also reported a growth in the participants' number, since 2012 until 2015.

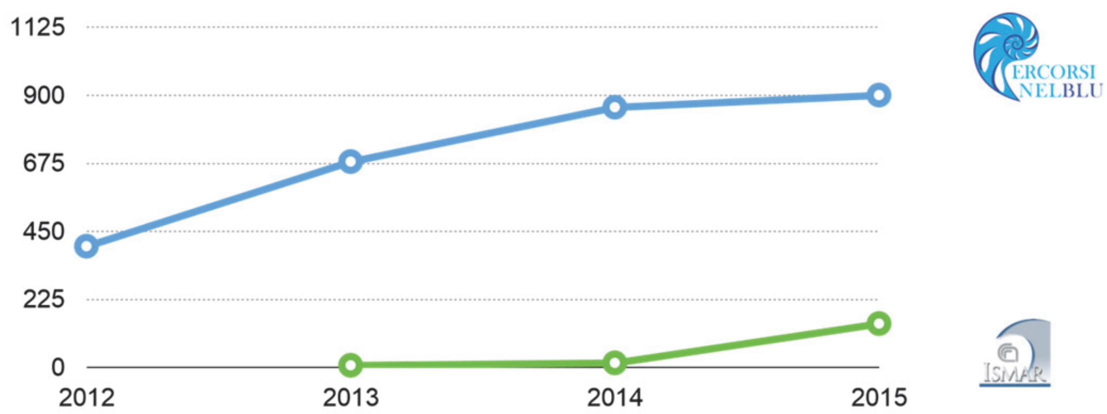

Figure 3. BluePaths and SeaCleaner have experimented a continues increase in the number of the involved participants (students, volunteers, etc.), from the year 2012 till 2015

Methods

The choice of the methodology to be used is one of the most important factors to consider when we want carry out a scientific investigation or design an educational path.

In our case, we deal with two kinds of methodology: a “scientific one”, for monitoring programs, and an “educational one”, for involving students in our projects with the aim to enhance their skill, interest and knowledge in marine scientific topics.

Here we describe only briefly the scientific methodology used for data collection and we address the reader, for a more detailed explanation, to dedicated publications (Merlino *et al.* 2015b).

Scientific methodology for surveys

Both projects provide data collected during repeated monitoring campaigns in the same place -Ligurian and North Tyrrhenian Sea (**Figure 2**) - and at a distance of months, to allow to deduce information on the type and rate of accumulation of materials (the biological one and the anthropogenic one), to estimate the possible origin and even make assumptions about the prevalence of marine currents and wave motion in the area under study.

SeaCleaner surveys are performed following MSF Directive (Directive 2008/56/EC, 2008; Galgani *et al.*, 2014) and an adapted version (see Merlino *et al.* 2015b) of the UNEP/IOC protocol (UNEP, 2012; Cheshire *et al.*, 2012); BluePaths is using the Reef-Check Protocol (C.E.M. Coastal Environment Monitoring Protocol, in http://www.progettomac.it/default_e.asp) integrating it with the experimentation of a new protocol recently defined (Mioni, 2015) of “snorkeling visual survey”, particularly adapt for young people and students without diving license.

Boths protocols provide instructions for surveyors about data collection in the field. Sampling of beached objects (the biological or anthropogenic ones) must be done walking across the beach methodically and carefully in a preselected and permanent transect line, parallel to the coastline. The BluePaths/Reef Check protocol is performed using a *quadrat*[5] and a “random sampling method” (Cerrano *et al.*, 2013, Mioni 2015); the SeaCleaner/MSFD establishes to take notes on the table/checklist of all the found objects, and removing them from the ground (Galgani *et al.* 2013). In our specific case, students have also developed a special tool (the App named SeaCleaner) in order to help surveyors in classification of the removed material in the different categories and dimensions (Merlino *et al.* 2015b).

Educational methodology

In our case, as we have a student population instead of skilled researchers or experts, we have to “educate” the surveyors before carrying on the monitoring programme. However, our final hope is to realize a comprehensive educational path that involves students not only in data collection, but also in problem definition before the surveys and in data analysis after them (Mioni &Merlino 2015b).

[5] The *quadrat* is a tool that marks off an exact area so that the objects in that area can be identified and counted. Sampling with quadrats is used for the study of ecology, especially biodiversity.

High school students participate mostly in SeaCleaner project and, in minor amount, in BluePaths project. They have been involved trough the educational instrument “work-related learning internships”[6]. They come from very different school typology, and have very different interest, skills and preparation. This fact, which initially appeared as a problem, has instead allowed to test a very interesting technique of teaching. In fact, we decided to assign them, inside the monitoring programme, a specific task, related to their scholastic background knowledge. Students belonging to schools with information technology (I.T.) curricula have dedicated more time to the SeaCleaner App elaboration (the “IT group”), while students coming from high schools with standard scientific curricula dedicated their time to data collection and their successive elaboration; in this case, we further divided the group in two parts: schools near the sea and schools far from the sea. The first ones follow researchers for sampling on the beach (“in situ” group), while the latter do, mostly, the job of data analysis (the "on office" group). Students belonging to a third category of school - a high school on graphics design - were involved in the design of the logo and of the web page dedicated to the project SeaCleaner (the “graphic” group).

The best way to obtain good results from all the “working groups” is to present to students the paths as a “problem-solving” programme, stimulating them to solve concrete problems (Inquiry-based learning, Krathwohl, 2002). In other word, in our two projects students become part of a research team; they receive new stimuli and take part in an investigation problem concerning the environment. Not only they learn directly from real data analysis, with important pedagogical advances (McDonnel *et al.*, 2015), but they contribute to collect their own data (“in situ” group) or to process them, following their specific skills (“on office” group, I.T. group and “graphic” group). This educational experience is highly motivating for students, and the scientific and technological output they contribute to produce represents a further positive stimulus, because they develop consciousness of having well done their job, and this increases their self-esteem (Morri & White, 2001).

We can divide the whole process in 5 steps, as reported in Table 1, following the 5E instructional model for teaching in science education (Merlino *et al.,* 2015a). As example, we describe briefly the 5E Model applied to BluePaths programme (last column) and to SeaCleaner programme (here only for the “in situ” group of students).

The application of the 5E model led inevitably to the use of the intrinsically related methodologies, as problem-solving and inquiring-based learning. But in the case of our two projects, we introduce also some original contributions, as the intensive use of “peer-education learning”[7] and of the “emotion-based learning” methodologies (Damasio *et al.*, 1994, Bechara *et al.* 2000).

[6] Work-related learning internship are, in Italy, compulsory for technical and professional schools since 2013 (Italian Legislative Decree n.77 of 15 April 2005) and, for all high school, from June 2015 (Italian Law no. 107 of 13 July 2015). Students’ ongoing work and /or support activities (for a total period of 400 hours in 3 years) are supervised by research centre/enterprise staff.

[7] Peer education is a term widely used to describe a range of initiatives where young people from a similar age group, background, culture and/or social status educate and inform each other about a wide variety of issues.

Peer education: an effective methodology to transfer and share knowledge and skills

According with the "work-related learning" directive, the students are requested to alternate periods in class with periods in working environment. SeaCleaner researchers have hosted different groups of students in different periods of the year. Involved students were not always the same people, from the beginning of the project (2013) to date (2015), but they change. In order to spend less time in preparing these students for the assigned work, we decided to give to the "outgoing students" the task to instruct the "ingoing students". So, during this "peer-educational" session, students who have already spent a period of several weeks working for SeaCleaner project, and are considered "experts", transfer the acquired knowledge to new students (their classmates or belonging to other schools).

The new students should continue the task assigned, inside the respective working group, during the following weeks or months, until, in turn, they become "tutors and teachers" for a new group of learners. During this process, the function of researchers was to check that the submitted information were actually the correct ones, without intervention except in cases of real need.

Emotion-based learning: not uniquely an involving instrument, but also a way to consolidate skills

Inside BluePaths teaching programme - a path initially mainly targeted for middle school but lately also addressed to high school – a very innovative educational instrument, i.e the "emotion-based" learning, has been introduced. In fact, this programme, like SeaCleaner, is based on the active participation of students in exploration and research projects on marine topics. In particular, beach

Table 1. These table describe the 5 steps of the educational process defined by the 5E instructional model for teaching in science education. For BluePaths, the detailed steps are reported in the last column. As in SeaCleaner project we divided the students in 4 sub groups, depending on their scholastic provenance, we describe in details the adopted strategy only for one of these sub groups (the “in situ” group)

5E Model	General purpose	SeaCleaner (“in situ” group)	BluePaths
Engage	Problem approach and presentation	Ask questions as “Marine litters: where they come from?”; “How did they arrive in the beach?” and “what can happen if they stay a long time on the beach?”	Ask questions as “how many kind of finding there are in the monitored beaches?”; “where did they come and what we can say about the environment surrounding the place where they have been discovered?”
Explore	Stimulate observation skills and intellectual curiosity, starting from the environmental potential offered by the natural area surrounding La Spezia itself offers	Encouraging the development of rational assumptions; disseminating the principles of experimental scientific method by teaching students the recollection, catalogation and classification methodologies for “field surveys” on marine litter. Moreover, give students basic notions of statistics and error analysis.	Encouraging the development of rational assumptions; disseminating the principles of experimental scientific method by teaching students the recollection, catalogation and classification methodologies for “field surveys” on biodiversity indicators. Moreover, give students basic notions of “random survey”, statistics and error analysis.
Explane	Hypothesis formulation	It is hard for students, in absence of previous knowledge, to understand the real causes of sea litter pollution. Therefore in class we help them by discussing the problem, proposing different possible explanation (proximity to river mouths, illegal dumping, etc).	It is hard for students, in absence of previous knowledge; understand the real causes for the death or damage suffered by some species. Therefore in class we help them by discussing the problem, proposing different possible explanation (different organisms have different necessities, and respond differently to external stimuli, etc.)
Elaborate	Elaboration in class of the collected material; preparation of tables and graphs. Discussion of the results and comparison with other ones, found in literature, elaborated by other students, etc..	From recollected material students produce their own graphs. They compare what was found on the different monitored beaches. For example: marine litter found near a river mouth it is more abundant than in other places far from rivers. We stimulate them to try consequences and possible explanation from their analysis.	Starting from recollected material, students compare what found on the different monitored beaches. For example: the differences between rocky and sandy environment influence the distribution and abundances of beached material. We stimulate them to try consequences and possible explanation from their analysis about biodiversity of the studied areal.

Evaluate	Elaboration of possible explications about faced problems. Often, more than one explication is possible! Students realize, in this way, that this is typical in scientific research, and “absolute truth” does not exist. This is the most important lesson we want they learn from this experience.	Students compare their previous hypothesis with data results. They now are able to give their own interpretation of them, and to support it with proofs. The success in this phase it shows that they have acquired the requested skills.	Students compare their previous hypothesis with data results. They now are able to give their own interpretation of them, and to support it with proofs. The success in this phase it shows that they have acquired the requested skills.

surveys on biological material take place in the area surrounding the place where students live, giving them, often for the first time in their life, the occasion to look in a new way to the environment around them, and discover things they never imagined.

This process has proved to be doubly useful, raising us from the time-consuming task of preparing students during each change of group, and giving us an extremely effective method of assessment of skills acquired by "outgoing students". Our experience of three years within the project SeaCleaner and, in part, in synergy with BluePaths, leads us to state that peer education is a teaching tool extremely useful and effective.

Always, after the monitoring phase it follows, in class, a second phase dedicated to the analysis, classification and catalogation of the objects found on the beach; finally, the third phase involves a discussion about the possible origin of the found biological objects, the importance of the presence of some specific “indicators” and the information that it is possible to draw from them about the state of the environment. The whole process is based on the 5E model for teaching in science education (see table 1), and bases its effectiveness in the emotional value that has, in this age group (11 to 14 years), the "personal involvement” in such activities. The validity of the "emotion-based learning" has been supported by several studies, thus confirming, with scientific data and brain studies, what, since a long time, many educators argued: the personal emotional involvement has an effect that goes beyond of a momentary raise of interest, but is able to trigger more deep processes, that lead to the retention of acquired concepts / skills acquired and avoid a mere superficial understanding (Damasio *et al.,* 1994; Bechara *et al.,* 2000). In our case, trough the participation in actions promoted by BluePaths, the students are not only attracted towards these scientific topics, but, above all, they manage to retain and consolidate the acquired knowledge thus learned in a more durable way, if compared with scholastic learning based on textbooks. This is confirmed by the results reported by these students in scientific matters: their academic performance improved significantly in the three years during which they were involved in BluePaths (science teachers of middle school “2 Giugno” of La Spezia, personal communication).

This fact is of considerable importance considering their future entry into the high school. The choices that the kids do in this age are often decided by parents, partly because the kids themselves have not developed personal opinions about what choices to make. Instead, the fact of having had the opportunity to assess, through direct experience, what it means to "act like a scientist", puts these young people capable of operating autonomously a conscious choice of their scholastic future.

Another very innovative tool developed by BluePaths tutors is the “snorkeling MAC protocol”. The Reef Check protocol, i.e. the international protocol used by environmental associations in their “citizen-science” surveys, often it turns to diving clubs, for underwater monitoring programs. Nevertheless, it is possible to sample the first sub-littoral zone, in rocky or sandy environment, without need of diving-tanks, but simply using snorkeling equipment. Moreover, in this case it is not necessary to have got the diving license, and so also very young people can participate. BluePaths established, so, a special protocol for sub-littoral surveys “MAC underwater” that can be following by middle or high school students. In this case, some selected student participate in intensive stages, learning the underwater technique for monitoring, using *quadrat* and special tools (underwater pens and panels), and work in little groups under the supervision of tutors (teachers or researchers). During those stages, middle and high school students work and collaborate, sharing experiences and leaning from each other, in a climate of cooperation and trust.

Figure 4. Snorkeling MAC protocol and citizen-science

In both projects the relationships between middle and high school students have been highly favored. Often high-school students act as tutors for the younger learners, but in some case it happens the contrary: middle school students, that follow BluePaths strategies during the three years of Italian middle school, are able to teach how to perform a biological survey, or an underwater monitoring program, (topics that are not included in the school programs!) to students of high school. In any case, peer education has represented a very important tool in our educational paths.

Figure 5. Peer learning education

Moreover, students of high and middle school interact also with University students, and also with citizens - not only parents and relatives- during volunteer campaigns for both kind of monitoring programs (citizen science and intergenerational education). These kinds of experiences are giving essential clues – to researchers and teachers – for improving and evaluating, in the future, this kind of informal teaching methods (Catarsi &Ciardi, 2010).

Last but not least, great importance, in both projects, is given also to the education of younger children. In accordance with the indication given in Recommendation number 4 of the European Commission (Osborne &Dillon 2008), we devote particular attention to scientific education also in primary school. We try to involve children, since the first scholastic years, in field activities, in similarity to what is done for middle school and high school, trying to devise, in this case, specific teaching strategies due to the age of the learners.

Results and discussion

Starting as two educational and scientific projects, independent from each other, BluePaths and SeaCleaner not only are now sharing the monitored area, but they also share students and methodologies, with a mutual exchange of experiences in peer and intergenerational education. Both projects have led to discover little-known aspects of disciplines that, usually, are just mentioned in class, and students have the opportunity to deepen their knowledge of some aspects of the world of environmental research, and to broaden their skillfulness and interests, according with the Recommendation 1 of the European Commission (Osborne &Dillon 2008).

The first visible result of the "sharing of forces" between the two project is the increase, from 2012 to 2015, not only of the number of students, schools and volunteers (**Figure 3**) , but also of MPA involved in the network (**Figure 2**). Moreover, also many local authorities, environmental laboratories etc. have been involved in activities devoted to disseminate the results of the two projects. As an example, we can quote the "Festa

Della Marineria" of La Spezia (Festa Della Marineria, 2015), the Clean up Europe day (Legambiente, 2015), the LABTER (the laboratory for environmental and territorial education) education day etc. In all these events many students of high and middle school were involved, as tutors, in hands-on laboratories, exhibitions and activities addressed to schools and to the general public (**Figure 6).**

Figure 6. Intergenerational education and awareness activities

An important evaluation instrument, for establishing the degree of efficacy of these kinds of approaches that we used, has been the questionnaire on science perception. Thanks to the collaboration of the WGSE (Working Group on Science Education) of La Spezia[8] (Locritani *et al.,* 2013), the questionnaire has been administered to high school students involved in SeaCleaner activities (Working Group "in situ" and "on office + IT"), during the scholastic years 2013/2014 and 2014/2015. The questionnaire aims to detect the degree of interest of students in scientific topics, and also the perception they have about the "scientist" work, distinguishing between female (F) and male (M) students. It is based on the model with response option in a 5-point Likert scale (Kind *et al.,* 2007). Comparison has been made with the results obtained by the administration of the questionnaire in a large sample of student population in La Spezia (pilot study) (Locritani *et al.*, 2015).

The post-activities results for the high school students questioned (**Table 2**) are positive, in the sense that the mean (considering both females and males) value for the 5 scientific aspects (indicators) considered (first column of table 2) is higher with respect to the pilot study, and especially this value grows after the activities (second administration). One of the reasons, however, of the generally higher value obtained also during the first administration, may be that in this case (SeaCleaner) students themselves decided to be involved in the project, indicating an initial major personal interest in the treated argument. Another aspect to be noted is the difference between females and males responses, with a major interest for science in males (about 5%).

[8] This Group born in 2013 after an intense period of science educational activities, carried on in collaboration by different research and educational centers of La Spezia.

Table 2: Results (extracted from Merlino *et al.* 2015c) concerning the degree of interest in science issues for 41 High School students involved in SeaCleaner. Two sub-sample of students have been investigated, considering first and second administration and finally compared with the pilot study results. **F** is for Females, **M** is for Males and **A** is for Average

	Percentage of satisfaction (%)												
Work-ing Group	**In situ**						**On office + I.T.**						**Pilot study**
Adm.	**First**			**Second**			**First**			**Second**			**First**
Gend.	**F**	**M**	**A**	**F**	**M**	**A**	**F**	**M**	**A**	**F**	**M**	**A**	**A**
Int. in science	33.3	57.1	45.2	63.5	58.3	60.9	50.0	56.4	53.2	33.3	57.1	45.2	44.7
Prop. for a pers. Scientific future	69.1	78.9	74	73.2	69.6	71.4	78.6	69.4	74.0	69.1	78.9	74.0	62.1
Percept.of social impor- tance of science	62.1	74.5	68.3	77.3	67.1	72.2	72.7	71.9	72.2	62.1	74.5	68.3	57.3
Scientificpercep-tion	53.9	58.5	56.2	52.8	58.3	55.5	75.0	79.8	77.4	62.5	76.2	69.3	64.7
Int. in extra-curricular activities	62.5	76.2	69.2	81.3	76.6	78.9	43.3	41.0	42.1	36.7	44.8	40.7	41.2

Also interesting is the comparison between the group of students working on beach monitoring (*in situ* group), with the group working only in data analysis and I.T. activities (*on office* + *I.T.* group). If we look the medium value, the interest in science is increasing (about 5%) for students who participate in the *in situ* activities and a decreasing (about 4%) for the students engaged only in the *on office* + *I.T.* work. But if we distinguish by gender, we note that there is an opposite trend for females and males: the first ones prefer the *in situ* activities, while the second ones prefer to work on office (note the decrease, in the last row, for the interest in extracurricular activities experimented by females of the "on office + I.C." group). It would be interesting to investigate the reasons of these differences and especially the reason of the great increase in female interest for science during *in situ* SeaCleaner internship (starting from 33.3 up till 63.5). A possible explanation could be finding in the family and environment influence. Female students are generally less stimulated and involved about scientific issues (by parents and by external inputs, as mass media, TV, science-movies etc). Possibly, class lectures, theoretical exercises etc. are not sufficiently stimulating to increase, in these girls, the low interest they have for science. So, female high school students participating to the "in situ" internship, probably begin the stage with very few "expectations". During the activities, instead, they realize that the proposed scientific activities are interesting and they change their science perception.

In any case, the questionnaire has been submitted, until now, to a restricted number of students, and the results are only qualitative. We need a higher number of students to statistically support these results, and we have chance for that, because the number of students involved in next SeaCleaner activities is highly grown (about 85 high school students scheduled for scholastic year 2015/2016).

We also would like to point out that the BluePaths "snorkeling MAC protocol" represent a real innovation, allowing, for the first time, very young students to participate in a scientific monitoring programme, and to collect real scientific data.

Also the SeaCleaner protocol represents an innovation for marine litter monitoring, as it is extremely friendly and easy to use; it is suitable for a wider circle of people (as volunteers) and - at the same time - methodologically sound and comprehensive, with respect to the MSFD protocol. The task of the students involved in SeaCleaner project was also to adapt the original protocol (more complete but too complex) in a kind of simplified inquiry, making it accessible to all.

This has led to increase the chances of involving volunteers and citizens in this type of monitoring, with obvious consequences both on problem knowledge and on problem awareness. Especially, the added value to this protocol has been the preparation of the associated App, elaborated by students involved in the first stage of work related learning, in 2013 (Merlino *et al.* 2015b).

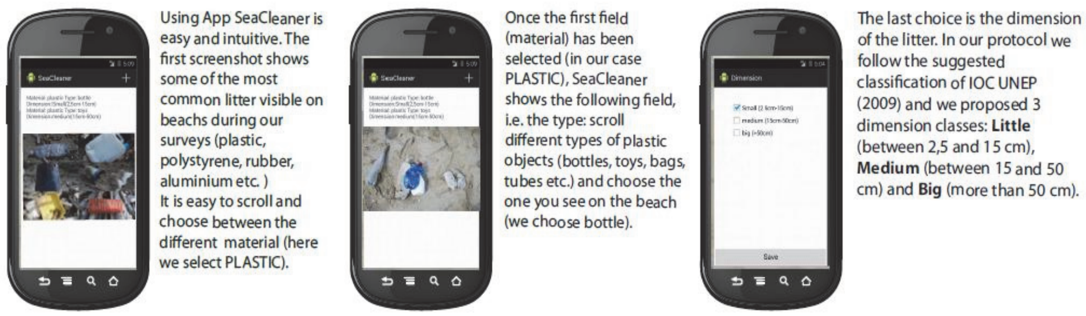

Figure 7. Application SeaCleaner, developed with the aim to be extremely "user-friendly following Guidelines of UNEP/IOC-"Quick poll" case (Cheshire *et al.* 2009). It has been conceived and elaborated by a group of students during an internship of work-related learning in 2013/2014

In 2016, thanks to the agreement for work-related learning internship with Secondary School "Fossati-da Passano" of La Spezia, the draft version of the GIS-based database will be finalized for the storage for data, maps and other information, and will be created the website for both SeaCleaner and BluePaths projects, in collaboration with ISMAR-CNR and INGV research centers.

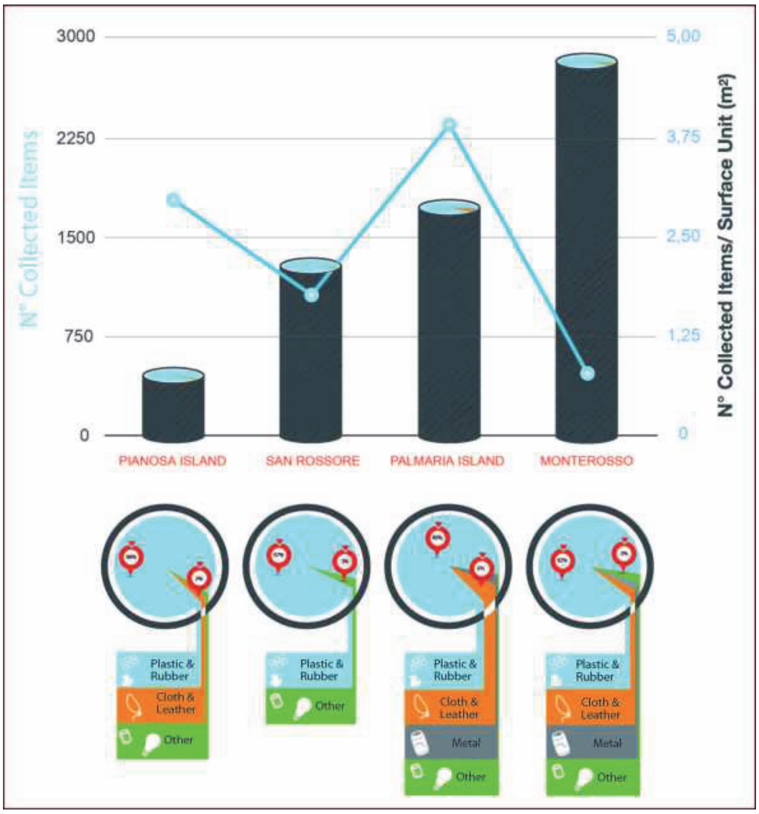

Figure 8. First scientific results about marine litter surveys, performed with the help of citizens, but particularly with high school students, have been presented through a poster during the IORC (International Ocean Research Conference) of Barcelona in 2014. The graphical layout and part of the content, for both the biological and the marine litter (table, graphs etc.) have been elaborated by students involved in the SeaCleaner project and in the Blue Paths project in the year 2013/2014

Apart from the scientific fallout (Merlino *et al.*, 2014a; Merlino *et al.*, 2014b; Merlino *et al.*, 2015a; Merlino *et al.*, 2015b; Mioni *et al.*, 2015a; Mioni & Merlino 2015b, Mioni 2015) useful for the researchers, the publication of the scientific results of the two projects (see Figure 8 as an example) represents an important push for involved scholastic institutes and students: they feel themselves proud to have contributed in scientific advances, to have their name between the acknowledged people or , in same case, among the authors (Merlino *et al.* 2014a), and to appear in documentaries and photos. Scholastic Institutes took part (and were awarded) in competitions for institutional prizes, proposing the two projects as examples of didactic paths addressed to create connections between education and real world. Some examples are the Special International Award Ramoge “Alain Vatricain” 2012-2013 for awareness towards protection of marine environments, and the “Acknowledgement as best-practice of work-related learning internships” during the 1st National Convention on work-related learning, ‘Salone dell’Orientamento’ ABCD of Genoa, in November 2013.

Last, but not least, the projects have been the subject of a documentary[9], realized in the context of the European Researchers' Night (MSCA - Marie Sklodowska-Curie Actions). The short movie tells, in an accessible and friendly way, the research carried out by the involved institutions in the area of Pelagos Sanctuary. Particular attention is

[9] Available in http://www.ismar.cnr.it/divulgazione/Video/video or in https://youtu.be/yMym-Rh6dgM in Italian language, and in https://www.youtube.com/watch?v=zwYZ1aCTlEw in French language.

given, in the movie, to the initiatives of citizen science, through which the educational experience often goes alongside with important scientific results. The movies have been translated in French language, and soon it will be translated also in Spanish and English languages.

Conclusions

Science has to become more and more challenging in the future, and a key role is played by education; an education aimed to avoid a mere accumulation of not controlled information, and of short-living concepts. It is, indeed, necessary to identify and develop, in students, the necessary skills and competences that will help them to "*participate in an effective and constructive way in social and working life in an increasingly diverse society*" (Recommendation of the European Parliament and of the Council, 2006/0962/EC).

To reach these objectives, an innovative pedagogical approach is necessary, to overcome traditional science teaching made of huge amount of concepts, often not related with the real world. Young people have to build a critical but conscious attitude towards technological innovation, scientific research and environmental issues, an attitude that will encourage the development of personalities able to make personal choices. To fulfill this aim requires a constant exercise on situations drawn from reality, and BluePaths and SeaCleaner projects are basing their educational and scientific approach on this methodology. Their interdisciplinary cooperation is an example of how education and research can pursue similar goals.

Next scientific goal will be the statistical analysis of correlations between parameters emerged from SeaCleaner survey (accumulation rates, fragmentation index, distribution - in different beaches - of different typology of material etc.) and biological data on biocenosis and benthic communities provided by BluePaths survey. We would like to remark that all these results would be impossible without the synergy of the two project and the help of volunteers and, especially, of the involved students.

Acknowledgements

The two project has been partly financed by P o l o DLTM, by CNR-ISMAR (through the EFRD "DeepGEN" Project), and by the European Commission's Research and Innovation Framework Programme H2020 (2014–2020), Marie Slodowska Curie action.

Thanks to the teachers (Tosi, Marini, Caselli,Manfredini,Vannucci, Pistelli,Traverso, Franceschini, Godani, and Casale) and to the ISA 2 dean Antonella Minucci; to Dr. Martucci, Eng. Bechini of Pisa University and to Dr. Marini of DLTM; to all the parks involved (Tuscan Archipelago National Park, Migliarino, San Rossore, Massaciuccoli Natural Park, Cinque Terre National Park, Porto Venere Natural Park, Montemarcello Natural Park); to Dr. Giacomazzi of the Laboratorio Territoriale di Educazione Ambientale–Comune della Spezia (LabTER); to all the involved students (of middle and high school) and researchers (Marina Locritani, Mascha Stroobant, Roberta Talamoni and Marco Bianucci).

References

Bechara, A., Damasio, H. and Damasio A.R. Emotion. (2000) *Decision making and the orbito-frontal cortex*, Cerebral Cortex 10, 3, 15-21. Oxford University Press, 2000.

Biggiero, L. (1998). Italian industrial districts: a Triple Helix pattern of problem solving, Industry and Higher Education. vol. 4. pp. 167-184.

Catarsi, E. & Ciardi, A. (2010). Guida alle attività di *peer education* nella scuola. Education, Centro Studi Bruno Ciari. Project: P.R.E.S.T.O. *Peer Related Education Supporting Tools* 142301 – LLP -1 – IT – COMENIUS –CMP. http://www.asevinnova.it/wpcontent/uploads/2012/07/27_PE_guide_IT.pdf.

Cerrano, C., Milanese, M, Mioni, E., Palma, M., Pantaleo, U., Previati, M., Rossi, G., Scinto, A., Turicchia, E. & Ponti, M. (2013). Reef Check Italia onlus: a network to improve civil participation in marine environment assessment. In: Riassunti del XXIII Congresso della Società Italiana di Ecologia (S.It.E.). 16-18 September. Ancona. [For more details visit: http://www.progettomac.it.

Cerrano, C., Di Camillo, C. G., Milanese, M., Previati, M., Rossi, G., Scinto, A.,Turicchia, E. & Ponti, M. (2012). Education Through Participation: the Role of Citizen Science in Marine Habitat Conservation. *New Perspectives in Science Education*, 436.

Cheshire, A.C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, E.T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M.A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B. & Westphalen, G. (2009). UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. UNEP Regional Seas Reports and Studies, No. 186; *IOC Technical Series* No. 83: xii + 120pp.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J., & Galloway, T. S. (2013). Microplastic ingestion by zooplankton. *Environmental Science and Technology*, 47(12): 6646–6655.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., & Galloway, T. S. (2015). The Impact of Polystyrene Microplastics on Feeding, Function and Fecundity in the Marine Copepod. *Calanus helgolandicus*. *Environmental Science & Technology*, 49(2): 1130–1137.

Corona, F., Cozzarelli, C., Palumbo, C., & Sibilio, M. (2013). Information Technology and Edutainment. *International Journal of Digital Literacy and Digital Competence*, 4(1): 12–18.

Damasio, A.R and Macaluso, F. (1994). Descartes' Error: Emotion, Reason and the Human Brain. In Random House (Ed.). New York, NY: Grosset/Putnam.

Directive 2008/56/EC of the European Parliament and of the Council, of 17 June 2008, establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), 2008. The European Parliament and the Council of the European Union. *Official Journal of the European Union*, 164/19–164/40.

Documenti e Studi degli Annali della Pubblica Istruzione, 83. (1998). Gli istituti comprensivi. Innovazioni organizzative e curriculari nel quadro dei processi di cambiamento del sistema scolastico. Le Monnier.

Eastman, L., Hidalgo-Ruz, V., Macaya-Caquilpan, V., Nunez, P., and Thiel, M. 2014. The potential for young citizen scientist projects: a case study of Chilean schoolchildren collecting data on marine litter. *J Integr Coast Zone Manage*. 14(4):569-79. http://dx.doi.org/10.5894/rgci507.

Etzkowitz, H. & Leydesdorff, L. (1995). The Triple Helix University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development, in *EASST Review*, 14, 1, pp. 14-19.

Ferraro, F. & Borroi, M. (1998). The emerging landscape of research: dynamics of trust and cooperation in university-industry relations. Triple Helix II Conference, New York/Purchase, January 1998.

Festa della Marineria. (2015).

Città di La Spezia: http://www.festadellamarineria.com/?lang=it.

Fossi, M.C., Coppola, D., Baini, M., Giannetti, M., Guerranti, C., Marsili, L., Panti, C., deSabata, E. & Clò, S. (2014). Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: The case studies of the Mediterranean basking shark (*Cetorhinus maximus*) and fin whale (*Balaenoptera physalus*). *Marine environmental research*, 100: 17-24.

Fossi, M. C., Panti, C., Guerranti, C., Coppola, D., Giannetti M., Marsili L., & Minutoli R., 2012. Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (*Balaenoptera physalus*). *Marine Pollution Bulletin*, 64: 2374–2379.

Galgani, F., Hanke, G., Werner, S. & De Vrees L. (2013). Marine litter within the European Marine Strategy Framework Directive. *ICES Journal of Marine Science* 70(6): 1055 – 1064.

Galgani, F., Claro, F., Depledge, M. & Fossi, C. (2014). Monitoring the impact of litter in large vertebrates in the Mediterranean Sea within the European Marine Strategy Framework Directive (MSFD): Constraints, specificities and recommendations. *Marine environmental research*: 1–7.

Gardner, P. L., 1975. Attitudes to science. Studies in Science Education, 2: 1–41.

Guile D., Griffiths T. Learning through work experience. *Journal of education and work*,14 (1) pp.113-131, 2001.

Hartley, B. L., Thompson, R. C., & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, 90(1-2): 209–217.

Hidalgo-Ruz, V. & Thiel, M. (2013). Distribution and abundance of small plastic debris on beaches in the SE Pacific (Chile): A study supported by a citizen science project. *Marine Environmental Research*, 87-88(August): 12–18.

Hörner, W., Döbert, H., von Kopp, B. & Mitter, W. (2007). The Education Systems of Europe Springer Science & Business Media, 887 pp.

Kind P.M., Jones K., Barmby P. (2007). Developing attitudes towards science measures. *International Journal of Science Education*, 29(7), 871-893.

INDIRE. (2013). Alternanza Scuola Lavoro, binomio possibile? Monitoraggio 2013 – Rapporto di Sintesi, Ottobre 2013. Report.

ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale). (2014). Sintesi dei risultati della consultazione pubblica 2014. Strategia per l'ambiente marino. Programmi di monitoraggio. http://www.strategiamarina.isprambiente.it/sintesi-risultati-consultazione-2014.

Italian Law no. 97 of 31 January 1994, New guidance for mountain areas - last important national law on mountain areas [Legge 31 gennaio 1994, n. 97 Nuove disposizioni per le zone montane. G.U. n.32 del 9-2-1994 - Suppl. Ordinario n. 24].

Italian Law no. 662 of 23 December 1996, Measures for Rationalising Public Finance, Official Gazette, issue no. 303 of 28 December 1996 [Legge 23 dicembre 1996, n. 662 "Misure di razionalizzazione della finanza pubblica" G.U. n.303 del 28.12.1996].

Italian Legislative Decree n.77 of 15 April 2005. General rules for work-related learning, Official Gazette, issue no. 103 of 5 May 2005 [D. Lgs 15/04/2005 n. 77 sulla "Definizione delle norme generali relative all'alternanza scuola-lavoro, a norma dell'articolo 4 della legge 28 marzo 2003, n. 53" Gazzetta Ufficiale n. 103 del 5 Maggio 2005].

Italian Law no. 107 of 13 July 2015, Reform of the national system of education and training and for the reorganization of the laws in force, Official Gazette, issue no. 162 of 15 July 2015 [Legge 13 luglio 2015, n. 107 "Riforma del sistema nazionale di istruzione e formazione e delega per il riordino delle disposizioni legislative vigenti" G.U. n.162 del 15.07.2015].

Legambiente. (2015). Final Report Legambiente_Beach litter. Igrass 2015: http://www.legambiente.it/sites/default/files/docs/legambiente_beach_litter_maggio_2015.pdf.

Locritani, M., Furia, S., Giacomazzi, F., Merlino, S., Mori, A., Nacini, F., Nardi, E., Stroobant, M., Talamoni, R., Zocco, O. (2013). La Spezia and the research network for outreach and education in marine sciences. In: Proceedings of European Geosciences Union General Assembly. Wien: EGU 2013, April 7-12, id EGU2013-8065. Bib. 2013EGUGA..15.8065L.

Locritani, M., Talamoni, R., Stroobant, M., Guccinelli, G., Benvenuti, L., Abbate, M., Batzu, I., Benedetti, A., Bernardini, M.I., Carmisciano, C., Casale, L., Centi, R., Furia, S., Giacomazzi, F., La tassa, H., marini, C., Merlino, S., mioni, E., Muccini, F., Nacini, F., Tosi, D. and Vannucci, C. (2015). Feeling the pulse of Public Perception of Science: does Research make our hearts beat faster? In: Proceeding of OCEANS'15 MTS/IEEE Conference: Discovering Sustainable Ocean Energy for a New World. Genova (May 18-21), Italy: IEEE. 9.

Lodola A, Savini D, Occhipinti-Ambrogi A (2012). First record of Tricellaria inopinata. (Bryozoa: Candidae) in the harbours of La Spezia and Olbia, Western Mediterranean Sea (Italy). *Marine Biodiversity Records* 5: e41, http://dx.doi.org/10. 1017/S1755267212000309.

McDonnel, J., Sage, L., Scott, G., Ferraro, C. & Hunter-Thomson, K. (2015). The challenges and opportunities of Using Data in teaching from the perspective of Undergraduate Oceanography Professors. *Mar Tech Soc Journal*, V49 "Blue Future: education new generations", n. 4, July/August 2015, pp.76 - 85.

Merlino, S., Stroobant, M., Mioni, E., Marini, C., Marini, D. & Giovacchini, A. (2014a). Marine Litter in Ligurian and Tyrrhenian Sea: a survey around the Cetacean Sanctuary coastline. In Proceeding of IORC (International Ocean Research Conference) 17-21 November 2014, Barcelona.

Merlino, S., Marini, C., Tosi, D., Caselli, L., Marini, D., Lucchinelli, P., Vatteroni, D., Lunardelli, F., Agrusa, A., Lombardi, D. & Stroobant, M. (2014b). Project SeaCleaner: from cooperation among ISMAR-CNR researchers, high school.

PART II

Assessment

Chapter 5

Assessment of problem-solving skills and capacity for applying knowledge in practice in subjects related to mechanical and materials engineering

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Abstract: The international accreditation for the Master and Bachelor degrees offered at our university, together with the demands of the employers, have made it clear that students' curricula should specify not only what they have studied, but also what they are actually able to do. Although the competence based curricula approach has been used in the development of the new programmes for Master and Bachelor degrees within the European Higher Education Area in recent years, the assessment of generic competences is still a pending task. This work presents an 'outcomes' approach for the assessment of the problem-solving skills and the capacity for applying knowledge in practice in subjects related to mechanical and materials engineering. In particular, this paper proposes an scale in order to quantify the level of achievement and shows some tools developed for this purpose. These tools are based on the evaluation of some learning outcomes that can be observed by using different strategies during the course. Conclusions about preliminary results and the difficulties found in order to create these tools and the scales are also described here.

Keywords: competence assessment; learning outcomes; problem-solving skills; capacity for applying knowledge in practice.

Introduction

In Sorbonne Declaration of 25th May, 1998 (Sorbonne, 1998), the four Ministers in charge for France, Germany, Italy and the United Kingdom signed a joint document on harmonisation of the architecture of the European higher education system. A common framework of reference was encouraged, aimed at improving external recognition and facilitating student mobility as well as employability. One year later, the Bologna Declaration of 29 European Ministers of Education was presented (Bologne, 1999). The process originates from the recognition that Europe is facing several challenges, such as the employability of graduates and the lack of skills in key areas. The European Higher Education Area (EHEA) is identified as an indispensable component to provide its students the necessary competences to confront the challenges of the new millennium. To consolidate this area and to promote the European system of higher education worldwide, compatibility of the systems has to be achieved, by developing comparable criteria and methodologies. This comparability should be guaranteed by the development of a common framework of qualifications, as well as by coherent quality assurance and accreditation/certification mechanisms.

As indicated in Reference (Agten, 2007), competences and learning outcomes are the basic parameters for the comparison between higher education from different universities and different countries. Therefore, Bachelor and Master Degree programmes developed at our university within the scope of the EHEA follow a competence based approach (Sursock *et al.*, 2010; Murias *et al.*, 2007; Rieckmann, 2012). These programmes clearly define the specific and generic competences to develop in each degree, in addition to the particular subjects along the degree.

The assessment of the specific competences is reflected on the students' curricula by using numerical qualifications, but the assessment of the generic competences is more difficult, in fact, it is a topic under research worldwide (Zlatkin-Troitschanskaia *et al.*, 2015), and it has been passed over somehow. It is understood that the students would have acquired these capacities and skills at the end of the studies, but the level of achievement is not assessed. The international accreditation of these programmes (Shuman, 2005), together with the requirements of the employers to have better information on the students' competences, have put the university to work on this issue (Andrews *et al.*, 2008; Entwistle *et al.*, 2004; Freire *et al.*, 2010). Also, recent regulations in Spain compel universities to guarantee the assessment of the competences developed on their degrees (MEC, 2007).

Our university, the Technical University of Valencia in Spain (Universitat Politècnica de Valencia, UPV), has started an institutional program to support research and experiences related to this topic (UPV, 2014). This work presents some results obtained in the frame of an innovative project (PIME program) on the evaluation of generic competences that have been traditionally worked in subjects of mechanical and materials engineering. In particular, the methodology and the tools developed for the assessment of the capacity for problem-solving and the capacity for applying knowledge in practice, using the name convention from Tuning project (2014).

The authors have focused on these generic competences because they are mentioned as key skills to prepare students for increasing social prosperity and their individual wealth in most frameworks all around the world (Kelly *et al.*, 2001, Young *et al.*, 2010); and they are also pointed as two of the most important skills required by the employers in Europe (Tuning brochure, 2014). Moreover, they believe that the mechanical and materials engineering subjects offer great opportunities to work on them. Therefore, they have already been doing it for a long time.

The authors belong to the Mechanical and Materials Engineering Department and they teach different subjects in different Degrees within the UPV: e.g., Machine and Mechanism Theory, Structural Integrity, Mechanical Vibrations and Materials Science. They found interesting to be able to test the tools developed in different academic levels in order to validate them.

The assessment of generic competences requires a change in the current pedagogical practices, as the lecture continues to be the dominant teaching method. The use of learning-oriented active methodologies is essential for the competences development (Salas, 2014), and it can be very helpful for their assessment as well. In fact, in the authors' opinion, one of the main challenges when dealing with the assessment of generic competences is creating evaluation activities that truly force the students to put their skills into play.

The authors have followed an Assessment for Learning approach (Bloom, 1981), as it seems very interesting to develop evaluation tasks that would not only allow to grade the students' performance, but also to be useful for the students to improve their capacities and their learning experience (McDowell, 2011).

Before explaining the methodology proposed for the assessment of these competences, the definitions used in this work will be stated in order to know what learning outcomes they are referring to. Then, the methodology based on the observation of these learning outcomes will be detailed, and the checklists developed will be shown. Next, some results regarding a first attempt to use these checklists in different subjects of Bachelor and Master Degrees are also described here. Finally, some conclusions are derived from this experience in order to improve the methodology in the future.

Definition of problem-solving skills

The definition used in this work for the competence on problem-solving refers to the ability to analyse and solve a problem in an effective way, identifying and determining the most relevant parts of it. The main aim when developing this competence is that the students increase their self-confidence and promote their own capabilities and skills to learn, understand and apply their knowledge. It is an important competence that contributes to the lifelong self-learning of the student, and helps in the developing of some other competences as team working, creativity, critical analysis and leadership.

It should be also noticed that problems are not exercises, i.e., problems refer to new open situations that encourage individuals to use new approaches (Pozo Municio *et al.*, 2009, Mourtos *et al.*, 2004). These situations can be solved by using different strategies, and they do not usually have only one solution. Solving a problem implies using thinking skills, and not only repeating a known procedure to obtain the solution.

From the previous work developed by the Institute of Education Sciences (UPV, 2014), a research centre belonging to our university that gives support to teaching, this competence can be decomposed in different learning outcomes that can be summarised as follows:

1. To identify a real problem and define precisely the most relevant facts.
2. To apply the methods learned to analyze a problem, gather relevant information and propose different alternative solutions.
3. Using the experience and judgment to generate an efficient and effective solution.

Definition of capacity for applying knowledge in practice

The definition used in this work for the capacity for applying knowledge in practice refers to capacity to identify the goals to solve one real situation and to establish a proper plan to do it, considering the uncertainties, constraints, resources and information available, and by using the knowledge and techniques learnt. It is a complex competence that integrates time and information management, and practical thinking, i.e. the action-oriented way of thinking that we use in daily life to adapt to new situations that arise, to take decisions and consequently to act (Villa *et al.*, 2008).

The students will also develop skills to justify their decisions in case of team working, and to think about how to verify that the plan is working as expected.

This competence can be decomposed in different learning outcomes that can be summarised as follows (UPV, 2014):

1. Using the own capacities and the suitable resources to identify the goals and to verify the quality of the information available.
2. To design a consistent plan with specific tasks to solve new and/or complex situations by its own, or in collaboration with others.
3. To define indicators to evaluate the plan progress and correcting measures to improve it in the future.

Methods

The use of rubrics for grading and feedback in higher education has become very usual to meet the requirements for consistency and transparency in generic competences assessment (Hack, 2015). They present some advantages for formative assessment with respect to other techniques, as can be found in Reference (Panadero, 2013). One example regarding the assessment of problem-solving skills can be found in Reference (Mendez *et al.*, 2011).

But, it is not easy to create a good general purpose rubric as the goals of the assessment have to be clearly defined (Lui *et al.*, 2014). In Reference (AACU, 2010) one example can be found, but there were still too many uncertainties and misunderstandings when trying to apply it. The authors of this work found it very difficult to create a suitable rubric for the assessment of both the problem-solving skills and the capacity for applying knowledge in practice. There were some discussions regarding the definitions, so it was not clear what the learning outcomes meant in some particular cases in different subjects, and it was very difficult to establish a grading that would be consistent among different markers.

Fortunately, rubrics are not the only way to carry this assessment out (Greiff *et al.*, 2013). In Reference (Hong *et al.*, 2015), a self-reporting questionnaire is used to assess different aspects of designer's reflection occurring during a design process, that is very similar to problem solving process: Identify goals; Gather information; Define the problem; Evaluate solutions; Making decisions. Also, an open-ended problem solved in teams is proposed in Reference (Mourtos *et al.*, 2014). In Reference (McMullan *et al.*, 2003) the use of portfolios is analysed.

Most of the aforementioned techniques would require a deep change into the learning-teaching method used to this time. So, finally, they decided to create checklists that would include some evidences related to the learning outcomes, and that could be easily adapted to different evaluation activities and subjects. These evaluation tools are not as accurate as rubrics can be, but they can be useful as a guideline for the students, and they are more easy to use for the markers. Moreover, a checklist meets most of the seven principles for good feedback practice (Nicol *et al.*, 2006):

1. It can help to clarify what a good performance is (goals, criteria, etc).
2. It facilitates the development of self-assessment (reflection).
3. It delivers some information to students about their learning.
4. It encourages teachers and peer dialogue around learning.

5. It encourages positive motivational beliefs and self-esteem.
6. It provides the opportunity to close the gap between current and desired performance.
7. It provides information to teachers that can be used to shape teaching.

To create these checklists some recommendations have been followed (Khus, 2001):

- Make sure your expectations match curriculum standards.
- Imagine what a good student response would look like.
- Think about parts of the task students would find difficult.
- Make sure that criteria are consistent with task directions.
- Decide which task features will not be assessed.
- Limit the number of criteria.
- Decide whether the evaluation tool will be specific or generic.

The checklists created in this work are detailed in **Tables 1** and **2**. They are structured in nine items in order to evaluate the different key aspects of the competences. For the problem-solving skills, the first learning outcome is divided into the first two items: the problem identification, and whether it is split up into smaller and easier units to solve, respectively. The second learning outcome is evaluated in items 3 to 6: the information gathering is reflected in item 3; regarding the proposed methodology, items 4-6 involve its description taking into account if several proposals are used to validate the resolution and if the choice of the followed method is justified, respectively. Finally, the last learning outcome is captured in items 7 to 9: item 7 refers to the estimation of the data for problem resolution and its justification, while item 8 comprises the analysis done of the problem solution guarantying the expected order of magnitude; and the efficacy in problem resolution is identified in item 9.

For the capacity for applying knowledge in practice, items 1 to 4 refer to the first learning outcome, i.e. defining the goals, taken into account the constraints and the information available. Items 5 to 7 capture the second learning outcome regarding the planning to solve the situation; and, finally, items 8 and 9 deal with the last learning outcome as they measure the plan execution.

Each of these items is assigned with a score from 0 to 3 when the level of achievement is “inappropriate”, “sufficient” and “appropriate”, respectively. In both cases, the score obtained when correcting the evaluation activity using the checklist is translated into increasing levels of achievement: “low”, “low-medium”, “medium”, “medium-high”, “high” and “master”. The “medium-high” level is the level expected when finishing the Bachelor Degree.

Study goal

As it has been stated in the Introduction section, the main goal of this work was to develop some evaluation tools to grade the level of achievement in two generic competences. To verify the usefulness of these tools, their consistency should be proved in two directions: the grade obtained from different markers (teachers, self-assessment or peer-assessment) for the same evaluation activities should be similar; but also, the grade should be higher for Master’s students than for the Bachelor ones, in general, as they are supposed to improve their capacities during the degree.

Table 1. Checklist for the assessment of problem-solving skills

	Checkpoint	Yes or no?	To what extent?
1	The student clearly identifies the object of the problem	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
2	The student splits the problem into simpler, more manageable parts	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
3	The student collects relevant information for the resolution of the problem	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
4	The student describes schematically the resolution procedure followed to obtain the solution	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
5	The student proposes several methods of resolution	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
6	The student states the methods used and justifies their utilization	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
7	The student justifies, if necessary, estimated values using its own knowledge and background	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
8	The student discusses or criticizes the solution obtained and compares it with the expected order of magnitude	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
9	The student is efficient to achieve the solution and does not need many detours	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐

** The answer **"No"** gives a score of 0 points. It is not necessary to complete the field "To what extent?"

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	TOTAL
Score										

PROBLEM SOLVING SCALE					
LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH	MASTER
From 0 to <5	From 5 to <10	From 10 to <14	From 14 to <18	From 18 to <23	From 23 to 27

Table 2. Checklist for the assessment of capacity for applying knowledge in practice

	Checkpoint	Yes or no?	To what extent?
1	The student clearly defines the goals to achieve by using its own words	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
2	The student identifies the constraints and the relevant facts to be taken into account	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
3	The student evaluates the quality of the information available	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
4	The student proposes reasonable estimations to overcome the uncertainties	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
5	The student works out a plan with suitable tasks depending on the information and resources available	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
6	The student proposes an effective solution taken into account the constraints and resources available	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
7	The student justifies the feasibility of the solution in front of other alternatives	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
8	The student establishes a method to control the plan progress	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
9	The student foresees feasible improvements of the plan	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐

** The answer **"No"** gives a score of 0 points. It is not necessary to complete the field "To what extent?"

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	TOTAL
Score										

CAPACITIY FOR APPLYING KNOWLEDGE IN PRACTICE SCALE					
LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH	MASTER
From 0 to <5	From 5 to <10	From 10 to <14	From 14 to <18	From 18 to <23	From 23 to 27

In order to check these consistencies, some preliminary tests have been conducted for both generic competences. A detailed description of these tests is given next.

Problem-solving skills

Sample

This competence has been evaluated in two subjects: Materials Science in the second year of the Bachelor's Degree in Chemical Engineering, and Mechanical Vibrations in the first year of the Master's Degree in Aeronautical Engineering. There were more than 70 students involved in Materials Science, and 20 in Mechanical Vibrations. There are 3 years of studies between them, at least for most of the students.

Procedure

The students were asked to solve an individual problem, rather more complex than the exercises done in the classroom. It forced them to follow the problem-solving process detailed in the checklist: from problem identification to critical analysis of solution, together with the information gathering, the proposed methodology as well as the reasoning to choose it. Proceeding in this way, the student is not only encourage to problem-solving, but also self-learning, based problems learning, critical thinking and written communication competence are promoted in an indirect manner.

The activity is presented in half an hour during one of the theory sessions. Then, the students have one month to deliver a written report. They are supposed to complete this activity in 8-10 hours, and they can attend some office hours in between.

Capacity for applying knowledge in practice

To carry out the evaluation of this competence, an appropriate activity must be designed. In this case, it is more subject dependent than the problem-solving skills, so it is very important to state clearly what it means to apply knowledge in practice in each subject. This evaluation activity should provide the students an opportunity to put most of the checkpoints of the checklist into play, but it depends on the academic year or level. As an example, the activities developed for two Bachelor's Degree subjects, together with the corresponding checklists are described next.

The first subject title is Machine and Mechanism Theory and it is taught in the second year of the Bachelor's Degree in Industrial Technologies Engineering. There were 50 students involved. It is an important subject on the fundamentals of Machine and Mechanism design and analysis, but students find it too theoretical. They are often not able to see that there are many real applications in daily life.

So, the following assignment is proposed, and the checklist in **Table 3** is used to correct it:

<u>First part:</u> *Look for or take a picture of a real mechanism*

You should be able to describe its operation and to draw a kinematic sketch.

<u>Second part:</u> *Define a design problem related to the mechanism*

- *Draw a kinematic sketch of the mechanism.*
- *Define the goals of the problem.*
- *Identify the motion range and all the constraints.*
- *Propose some input data and estimate the mass properties of the links.*

- *Detail the solving process, pointing out the variables to find and justifying the procedure you would follow.*
- *Explain how you would be able to check the solution obtained.*
- Make a comment on how to improve the performance of the mechanism.

The activity is presented in one of the theory sessions. They are asked to group in teams of 3-4. Then, the students have one month to deliver a written report. They are supposed to complete this activity in 8-10 hours, and they can attend some office hours in between.

The title of the second subject is Computer Aided Mechanical Design and it is taught in the last year of the Bachelor's Degree in Industrial Technologies Engineering. There were about 35 students involved. The main topic of the subject is the dynamic simulation of multibody systems by using the commercial software ADAMS/View (ADAMS, 2014). During the course, the students have to develop a model of a V4-cylinder internal combustion engine, using parts of a mono-cylinder engine (see **Figure 1**).

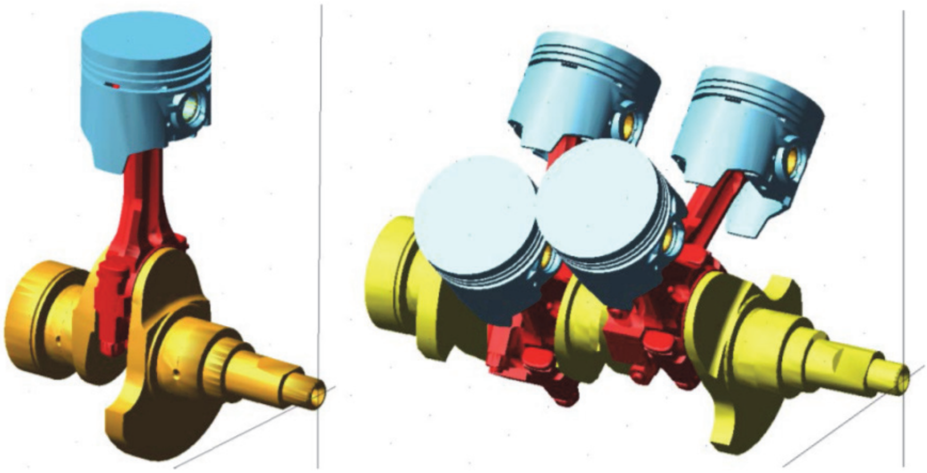

Figure 1. V4-cylinder internal combustion engine model in ADAMS/View

The engine is originally built by the students using some parts that have been modelled in a CAD software. The goal is to simulate the steady-state dynamics of the engine. In an intermediate step, the students model a 3-cylinder engine during a lab work session by following some instructions from the teacher. So, the modelling procedure is shown to the students, and they learn how to build it. The modelling process includes grouping and copying some parts, e.g. the crankshaft, the connecting rod, the piston, etc; joining the different parts through kinematic pairs; moving and placing them into accurate locations and with accurate orientations; applying forces and programming the engine operation.

This assignment is suitable for the assessment of the capacity for applying knowledge in practice as there is not one best solution to model the engine, and so, students face a similar situation to the ones they have solved in lab work sessions, but there are some uncertainties they have to overcome. There are a lot of different sequences and options to be used in order to build the model in an efficient way. There are some decisions to take so that the model works properly, and they have to think about how they can detect if it is doing so. Moreover, the evaluation task is not only the correct modelling of the engine, but they also have to write a tutorial including all the figures and necessary instructions for a beginner in ADAMS/View to build the model.

Table 3. Checklist for the assessment of capacity for applying knowledge in practice in Machine and Mechanism Theory subject

	Checkpoint	Yes or no?	To what extent?
1	Have you understood what you are asked to do? *Write the table of contents of the assignment*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
2	Are you sure what kind of mechanism can you solve? *Check the mobility of the mechanism and the kinematic pairs used*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
3	Can you identify all the parts of the mechanism? *Draw a kinematic sketch*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
4	Do you have all the mass properties and the geometry you need? *Identify any uncertainties and make an estimation to overcome them*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
5	Do you know how to analyze the kinematics and the dynamics of the mechanism? *State the steps to follow and the methods you need*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
6	Can you propose a design problem? *Write the design requirements*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
7	Why do you think this is an interesting problem? *Argue it*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
8	What should it be the order of magnitude of the solution? *Anticipate the range of numerical values for the solution*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
9	Do you think it is possible to improve the mechanism' performance? *Explain how to do this*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐

** The answer **"No"** gives a score of 0 points. It is not necessary to complete the field "To what extent?"

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	TOTAL
Score										

CAPACITIY FOR APPLYING KNOWLEDGE IN PRACTICE SCALE					
LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH	MASTER
From 0 to <5	From 5 to <10	From 10 to <14	From 14 to <18	From 18 to <23	From 23 to 27

Table 4. Checklist for the assessment of capacity for applying knowledge in practice in Computer Aided Mechanical Design subject

	Checkpoint	Yes or no?	To what extent?
1	Have you understood what you are asked to do? *Explain it in your own words*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
2	Are instructions clear? *Write the table of contents of the assignment*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
3	Can you understand the kinematic and the operation diagrams you have provided with? *Draw a graph with the pistons position as a function of the crankshaft rotation*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
4	Do you have all the parts you need? *Identify any part you miss and explain how you are going to overcome it*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
5	Do you know all the steps you have to follow to complete the assignment? *Enumerate the sequence of task you need to follow*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
6	Do you accurately describe the tasks to do? *Detail the instructions*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
7	Would there be any other procedures to build the model? *Argue the advantages and drawbacks of your proposal*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
8	Could you check if your instructions are correct without assembling all the model? *Note the critical points in the assembly*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐
9	Do you think you could improve your instructions after a few uses? *Explain how you could do this*	Yes ☐ No ☐	1. Inappropiate ☐ 2. Sufficient ☐ 3. Appropiate ☐

** The answer **"No"** gives a score of 0 points. It is not necessary to complete the field "To what extent?"

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	TOTAL
Score										

CAPACITIY FOR APPLYING KNOWLEDGE IN PRACTICE SCALE					
LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH	MASTER
From 0 to <5	From 5 to <10	From 10 to <14	From 14 to <18	From 18 to <23	From 23 to 27

The students are provided with the engine operation sequence and a list of requirements, as well as the original checklist for the assessment of the capacity to apply knowledge in practice adapted for this particular assignment and subject, as shown in **Table 4**.

The activity is presented in one of the lab work sessions. They have to work in pairs, as they are already grouped in the computer lab. The students have one month to deliver a written report. They are supposed to complete this activity in 10-12 hours, and they can attend some office hours in between.

Results and Discussion

Problem-solving skills

For the Master students it was possible to check the consistency among different markers, as the written reports were under review of two teachers. The grading given by both of them for every student was very close.

Figure 2 shows the score after the problems correction. This evaluation has been carried out by using the checklist in **Table 1**, where each item is scored on a 0-3 range, and the maximum score for activity is 27 points. In **Figure 2a)** the final score for each evaluated problem is detailed, for Bachelor degree and Master students. In all the evidences collected during the course, a higher final score is observed for Master students compared to Bachelor degree students. If the analysis is performed for each item defined in the checklist (except item 5 that has been discarded because it could not be assessed in the Bachelor degree problems), as shown in **Figure 2b)**, the average score on each checkpoint for Master students is again higher than the one corresponding to Bachelor degree students. It is important to note that the evaluations of items 7 and 8 show the lowest scores, associated with a poor justification of the used data and insufficient analysis of results, respectively.

Figure 3 is obtained if the items are grouped into learning outcomes, as discussed in the previous section. The score is reflected in terms of percentage of the total score. It should be noted that in the first learning outcome there is little discrepancy (3.5%) between Bachelor degree and Master students, that is, both are able to identify the objective of the problem and split into simpler parts. Regarding the second learning outcome, which is based on the collection of information, description and justification of the methodology followed to solve the problem, a notable discrepancy (19%) is observed, the Master students showing higher skills. Finally, in the third learning outcome, there is a large discrepancy between Master and Bachelor degree students, 52% approximately. Therefore, Master students have greater skills to estimate and justify problem data, critically analyse the solution and do it effectively and efficiently.

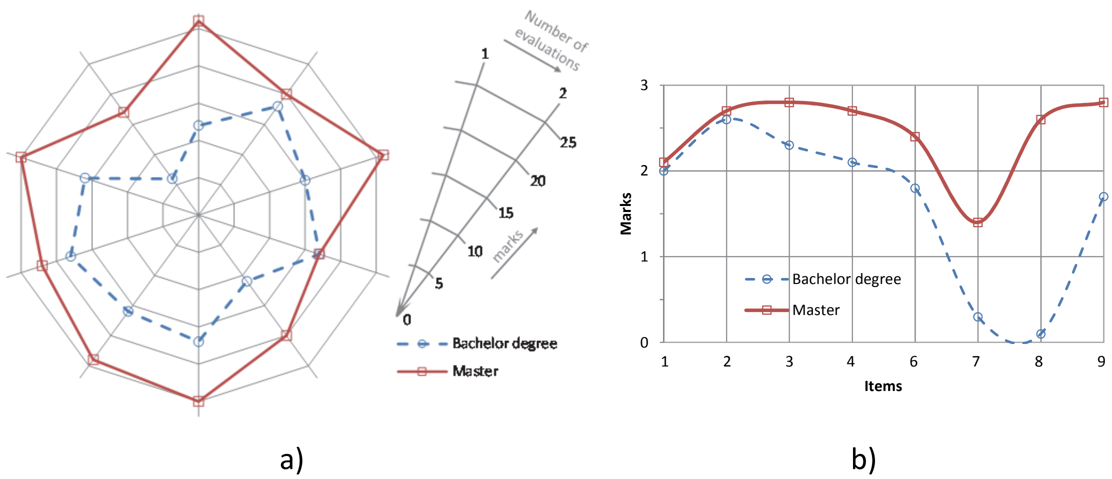

Figure 2. Marks obtained on the different evidences collected during the course for Bachelor degree and Master students. a) Final marks from Checklist. b) Average marks for each item of Checklist

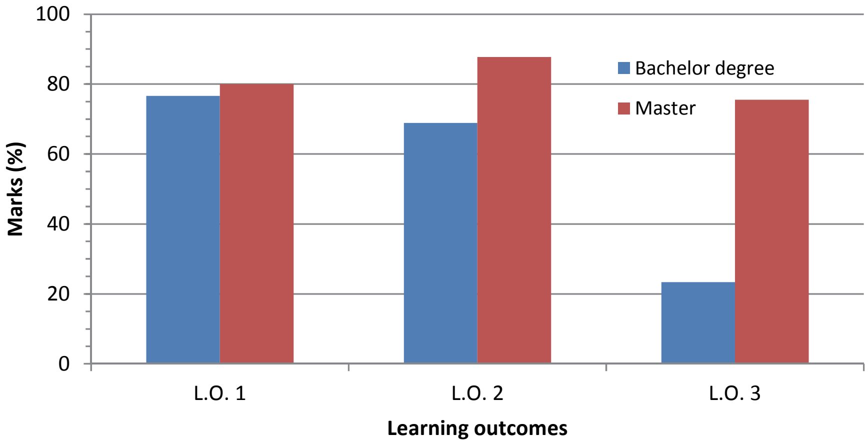

Figure 3. Percentage marks obtained on three learning outcomes for Bachelor degree and Master students

Taking into account that the aim of the work is to develop a methodology able to evaluate the competence on problem solving, **Figure 4** details the assessment of such competence for Bachelor degree and Master students by applying the methodology described before. Regarding Bachelor degree students, it is observed that 80% of them reach levels of competence framed in the first 4 levels associated with Bachelor degree courses. As it can be seen, the approximate distribution yields 10% "low-medium" level, 20% "medium" level and 50% "medium-high" level, the remaining being 20% "high" level, reserved for Master skills. On the other hand, it is observed that the level achieved by Master students is higher than that for Bachelor degree students, as expected. In this case, 80% of Master students are in areas associated with Master courses (last two levels), 30% being "high" level and 50% reaching "master" level. The remaining 20% has a "medium-high" level associated with the last course of Bachelor degree.

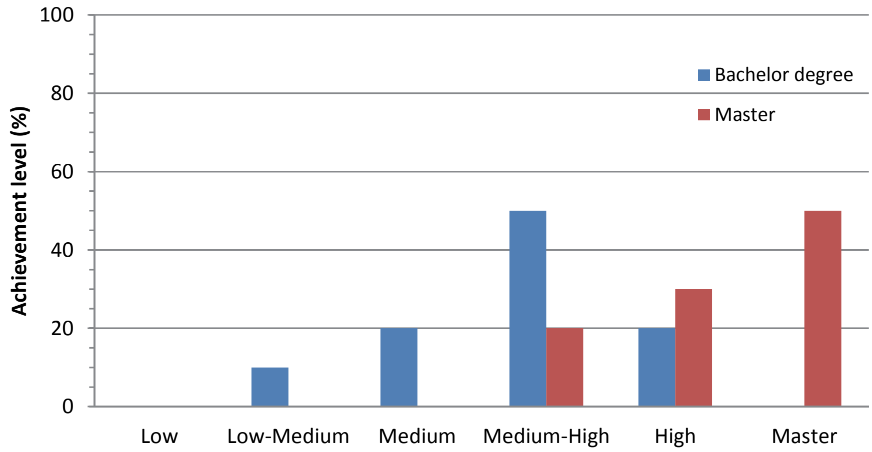

Figure 4. Comparison of competence achievement levels for Bachelor degree and Master students

After analysing the different results, that is, the individual items' assessment, the total scores of evidences and the achievement levels, it is observed in all of them that Master students have acquired more skills to solve problems than Bachelor ones, as expected. Therefore it can be stated that the methodology described for carrying out the assessment of the problem solving competence is effective and reliable, from activity and assessment tool to the definition of its learning outcomes and achievement levels.

Capacity for applying knowledge in practice

The preliminary tests in Machine and Mechanism Theory have not been very fruitful. As the assignment was not mandatory for the students, only one third of them have done it. Moreover, it was noticed that the instructions given to the students and their presentation in the classroom had to be improved next year so that the students actually understand what they were asked to do. Most of them have slightly modified some exercises that they have found in the handbooks listed in the references, not the kind of design problems that were expected to be.

Regarding the experience in the subject of Computer Aided Mechanical Design, it was much more promising. Most of the students were very motivated, what can be due to the fact that the mark obtained in this assignment was considered into the final mark in the subject, but also because they found it very real and useful.

By using the scale proposed, half of the students were in the "medium" level, while the other half were in the "medium-high" level, as expected. In this case, it has not been possible to validate the consistency of the evaluation tool through the academic years. But the consistency of the checklist considering different markers was proved as there were three different teachers on this task.

Conclusions

A methodology has been defined to carry out the assessment of the problem-solving skills and the capacity for applying knowledge in practice in Bachelor's and Master's Degrees of the Technical University of Valencia, in Spain. For this purpose, specific activities have to be proposed to the students and a checklist is used as the evaluation tool.

The proposed methodology has been proved in Bachelor's and Master's Degrees courses, and the results have been analyzed. For the problem-solving skills, after comparing the levels of achievement, the Master students show competence levels mostly "high" and "master", while Bachelor degree students are located on "medium" and "medium-high" levels. As expected, Master students have more skills than Bachelor degree students, so it can be concluded that the proposed methodology is valid and reliable to perform the assessment of the problem-solving skills.

For the capacity for applying knowledge in practice, it has not been possible to obtain such quantitative results as for problem-solving skills.

The main conclusions obtained from this experience, which can be useful as guidelines for any reader interested in using these methodology, are:

- The assessment of the generic competences should be done together with the assessment of the specific ones. So, evaluation activities that allow the teachers to assess the scientific-technical competences, but at the same time, force the students to put the generic ones into play, seem to be the best method to increase the students' motivation and to improve their self-regulation. By doing so, the learning experience is clearly enhanced for both students and teachers.
- For this kind of activities to be actually profitable for the students to improve their capacities, a notable amount of time will be required. This time should be considered when planning the schedule of the subject. These activities should be detailed to the students, some office hours should be dedicated to follow the process, and some time at the end of the course should be devoted to give a good feedback to the students.
- The authors have found it very interesting to develop checklists adapted to each subject and task, so that they are easy to correct and very clear for the students. But, when creating these checklists, the learning outcomes of the competence should always be kept in mind, as this is a generic competence and it should be useful in any other subject.
- Finally, to keep a good consistency when different markers are using these checklists, it is very important to clearly define what does it mean "To what extent" for each of the items, adapted to the particular task and subject. This discussion can be very fruitful for improving the teaching-learning process.

As this experience has been very well valued by the teachers, and also by the students, further improvements are planned for next years:

- To include the activities dedication hours within the subject schedule, so that there is plenty of time to complete them properly.
- To keep on checking the tools consistency using all the data from different years and degrees.
- To continue thinking about these issues and to try to find new methodologies and activities in order to have more possibilities to achieve the generic competences' assessment.

Acknowledgements

The authors acknowledge the financial contribution of Universitat Politècnica de València through the project PIME/2014/A/012/B.

References

AACU. (2010). *Problem solving VALUE rubric*. Retrieved July 22, 2014, from https://www.aacu.org/value/rubrics/problem-solving

Adams team at MSC Software. (2014). Adams Tutorial Kit for Mechanical Engineering Courses. MSC Software.

Agten, J. (2007). Bologna as a frame for Competence Based Learning and Supervision? Katholieke Hogeschool Kempen. Retrieved September 29, 2015, from http://www.eassw.org

Andrews, J. & Higson, H. (2008). Graduate employability, 'Soft skills' versus 'Hard' business knowledge: A european study. Higher Education in Europe, 33, 411-422.

Bloom, B. S., Madaus, G. F. & Hastings, J. T. (1981). Evaluation to Improve Learning. New York: McGraw-Hill.

Bologne Declaration (1999). Retrieved September 29, 2015, from http://www.ehea.info/article-details.aspx?ArticleId=3

Entwistle, N. J. & Peterson, E. R. (2004). Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments. International Journal of Educational Research, 41, 407-428.

Freire Seoane, M. & Teijeiro Alvarez, M. (2010). Competences of graduates as an indicator of external quality assurance in universities. Regional and Sectoral Economic Studies, 10 (3), 77-91.

Greiff, S., Holt, D. V. & Funke, J. (2013). Perspectives on problem solving in cognitive research and educational assessment: analytical, interactive, and collaborative problem solving. Journal of Problem Solving, 5, 71-91.

Hack, C. (2015). Analytical rubrics in higher education: A repository of empirical data. British Journal of Educational Technology. DOI: 10.1111/bjet.12304

Hong, Y.C. & Choi, I. (2015). Assessing reflective thinking in solving design problems: The development of a questionnaire. British Journal of Educational Technology, 46 (4), 848-863. DOI: 10.1111/bjet.12181

Kelly, A. (2001). The evolution of key skills: towards a tawney paradigm. Journal of Vocational Education & Training, 53 (1), 21-36.
DOI: 10.1080/13636820100200149

Khus, T.M., Johnson, R.L., Agruso, S.A. & Monrad, D. M. (2001).
Put to the test: Tools & Techniques for Classroom - Chapter 4.
https://www.heinemann.com/shared/onlineresources/e00278/chapter4.pdf

Liu, O.L., Frankel, L. & Crotts-Roohr, K. (2014). Assessing critical thinking in higher education: current state and directions for next-generation asssessment. ETS Research Report 14-10: Wiley Online Library. DOI:10.1002/ets2.12009

McDowell, L., Wakelin, D., Montgomery, C. & King, S. (2011). Does assessment for learning make a difference? The development of a questionnaire to explore the student response. Assessment & Evaluation in Higher Education, 36 (7), 749-765. DOI: 10.1080/02602938.2010.488792

McMullan, M., Endacott, R., Gray, M.A., Jasper, M., Miller, C.M.L., Scholes, J. & Webb, C. (2003). Portfolios and assessment of competence: a review of the literature. Journal of Advanced Nursing, 41 (3), 283-294.

MEC (2007). Real Decreto 1393/2007, de 29 de octubre, por el que se establece la ordenación de las enseñanzas universitarias oficiales. Ministerio de Educación y Ciencia, Spanish Government. BOE-A-2007-18770

Méndez, A., Jiménez de Cisneros, B., Fernández, C., Molleda, C., Sadornil, E., Manrique, E., Montoro, T., & Torres, R. (2011). A model for evaluation of generic competences in engineering: Application to the problem-solving competence at UPM. Proceedings of Research in Engineering Education Symposium, Madrid, Spain.

Mourtos, N.J., DeJong Okamoto, N.C. & Rhee, J. (2004). Defining, Teaching, and Assessing Problem-Solving Skills. Proceedings of the 7th UICEE Annual Conference on Engineering Education, Mumbai, India.

Mourtos, N.J., DeJong Okamoto, N.C. & Rhee, J. (2004). Open-Ended Problem-Solving Skills in Thermal-Fluids Engineering. Global Journal of Engineering Education, 8 (2), 189-200.

Murias, P., de Miguel, J. C. & Rodríguez, D. (2007). A composite indicator for university quality assesment: The case of Spanish higher education system. Social Indicators research, 89, 129-146.

Nicol, D. & MacFarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. Studies in Higher Education, 31 (2), 199-218. DOI: 10.1080/03075070600572090

Panadero, E. & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisited: A review. Educational Research Review, 9, 129-144. DOI: http://dx.doi.org/10.1016/j.edurev.2013.01.002

Pozo Municio, J.I., & Pérez Echevarría, M.P (2009). Psicología del aprendizaje universitario. Madrid: Morata.

Rieckmann, M. (2012). Future-oriented higher education: Which key competencies should be fostered through university teaching and learning?. Futures, 44, 127-135.

Salas, M. (2014). Do higher education institutions make a difference in competence development? A model of competence production at university. Higher Education, 68, 503-523. DOI: 10.1007/s10734-014-9725-1

Shuman, L. J., Besterfield-Sacre, M. & McGourty, J. (2005). The ABET "Professional Skills"—Can they be taught? Can they be assessed? Journal of Engineering Education, 94 (1), 41-55.

Sorbonne Joint Declaration (1998). Joint declaration on harmonisation of the architecture of the European higher education system. Retrieved September 29, 2015, from http://www.ehea.info/article-details.aspx?ArticleId=3

Sursock, A. & Smidt, H. (2010). Trends 2010: A decade of change in european higher education. Brussels: European University Association.

Tuning project. (2014). Approaches to teaching, learning and assessment in competences based degree programmes. Retrieved July 22, 2014, from http://www.unideusto.org/tuningeu/teaching-learning-a-assessment.html

Tuning brochure. (2014). Tuning Project: General Brochure. Retrieved July 22, 2014, from http://www.unideusto.org/tuningeu/documents.html

UPV (2014). Competencias Transversales. http://competencias.webs.upv.es/wp/

Villa, A. & Poblete, M. (2008). Competence-based learning: A proposal for the assessment of generic competences. Bilbao: University of Deusto.

Young, J. & Chapman, E. (2010). Generic competency frameworks: A brief historical overview. Education Research and Perspectives, 37 (1), 1-24.

Zlatkin-Troitschanskaia, O., Shavelson, R.J. & Kuhn, C. (2015). The international state of research on measurement of competency in higher education. Studies in Higher Education, 40 (3), 393-411. DOI: 10.1080/03075079.2015.1004241.

Chapter 6

The role of metacognitive monitoring in adult learning in online context

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Abstract: This paper examines the reflexions made by a set of online students regarding the results obtained in an assessment task and its consequences for the future. The sample included 43 students in continuous assessment, from both sexes. After knowing the results they were asked to indicate the implications of this exercise to their future studies. The content analysis revealed the existence of two categories - Causality (intrinsic / extrinsic) and Influence (Generics/ Specifics/No consequences) - regardless of the approach to real evaluation. The reflection that students can make about their learning process and the difficulties in developing their tasks is of great relevance to achieve success. This was evident in the analysis that our students made on the completion of the assessment work, as well as the consequences for their future study. This process of reflection and awareness in the teaching learning process is particularly relevant in online education where the role of metacognitive monitoring and control system gains a prominent role. Allowing students to reflect on these issues permits them to be more effective learners.

Keywords: metacognition; adult learning; online learning

Introduction

Technological advances have been giving a new face to distance learning systems. ICTs open new perspectives to facilitate learning. They work as tools that complement the education system, and constitute themselves as a real and basic support for training.

This new format implies methodological, pedagogical, psychological and even emotional changes with consequent modifications in roles and functions of the actors involved in it. These new learning scenarios lead to a change of attitude and posture relative to this whole process. This change should be taken into account on both sides - learners and teachers.

Students in eLearning require greater self-direction and self-regulation to achieve their academic goals (Bol & Garner, 2011). To lead the students to reflect on their learning strategy and tailor their metacognitive strategies to achieve success in the task is of great relevance. This means that the incorporation of ICT in the educational context, using the virtual spaces, allows a more effective response to the educational challenges, thanks to the use of strategies and tools that best fit to the real needs of their learners. The research works of Azevedo and Cromley (2004) points to the implications that the design of virtual learning environments have on the acquisition of knowledge.

> (…) The most critical problem-solving skills that is so much talked about in modern training taxonomies is the resolution of their own metacognitive equation. Thus, the new illiteracy is not so much lack of knowledge; it will reside mainly in the absence of learning skills (...) (p.33).

Research has shown the implications of self-knowledge of one's mental processes have for academic success. Conditions must be created to help thought in such processes. This requirement is extremely relevant when we place it in online education system, which advocates independence for students. This work will anchor itself, from a theoretical point of view, with two main topics: the first regards the issues of metacognition in paragraph “Metacognition: monitoring and control” -, and the second will focus on the particularities and challenges of online learning contexts.

Metacognition: monitoring and control

We learn ever more outside formal learning contexts and periods formally defined for it. The rapid and constant changes in our society as well as developments, on a technological level, require constant updating of knowledge, providing, like this, constant learning opportunities. It is in this context that the knowledge that each person has in dealing with learning activities, becomes a powerful tool nowadays (Bjork, Dunlosky & Kornell, 2013). The awareness of learning activities and associated processes promotes understanding, retention and transfer of learning.

Leclercq and Denis (1995) defined a good learner as “a person who solves learning problems” (p.155); that is a good regulator of their own learning. For them learning is a “regulated process of problem solving” (p.155). This process can be decomposed into six major phases and a good learner is one who can manage well each one. This process requires analyzing needs, setting goals, planning of learning strategies, executing, observing and ultimately deciding. The same can be operationalized as follows:

Table 1. Stages of the regulation process

Concerning to ...	The learner ...
... *analysis of the* ***needs***	... should realize they need to learn and *why* learning *is needed*.
... *definition of the* ***objectives***	... need to learn what is needed; is learning *what* .
... *planning* ***strategies***	... should know when, how (what methods), at what pace, with whom.
... ***execution***	... must perform truly what was expected. Many learners know what they need to do and how to do it, but they don't do it.
...***observation***	... must be able to assess his own learning level, to know what the goals are and his progress.
... ***decisions***	... must be able, if necessary, to modify the antecedent steps.

Hacker et al (2009) refer that learners can be agents of their own thoughts and behaviors, can monitor their knowledge or skills, establish their learning objectives, outline and control strategies / plan to achieve them, monitor progress for their possible adjustments and, finally, assess whether the objectives were achieved. All this translates into what Zimmerman (2000[a]) calls self-regulation of behavior. According to this author the concept of self-regulation can be defined as self-generated thoughts, feelings and actions for attaining academics goals (Zimmerman, 1998). The key element of self-regulation is self-monitoring that involves the observation and monitoring of the performance itself, as well as its results. This in order to understand their learning process and apply these strategies in future situations, where they will prove to be adequate – Figure 1.

Figure 1. A cyclical model of self-regulated learning (Zimmerman, 1998, pag. 83)

According to Serra and Metcalfe (2007) the following aspects have been associated to the concept of metacognition - knowledge about the process, about their monitoring and their control -. The learning process leads to a continuous self-evaluation and a consequent decision on what to do with the information collected: What's next? What do I need to study more? Have I study this content? What strategies will be used? (Goulão, 2009).

According to Bjork, Dunlosky and Kornell (2013) for learners to become effective in the learning process, they should "not only be able to assess accurately the states of their own learning, but also be able to manage it and the activities in response to such monitoring" (pag. 422).

We can say that competent learners feel themselves responsible for their own learning and play an active role in the process. They know how to plan learning by analyzing the requirements and by managing the process in order to achieve the goals they have set to themselves. For this, the learner knows how to distinguish what types of intellectual operations are needed to use, the learner knows to choose the teaching methods and materials that are needed and that best suit the learner's learning style, and finally, he/she knows to make decisions and to ask questions that allow to move forward and to evaluate trends. This active role allows the learner to be observant and intervening in context by setting goals and pursuing to achieve them.

By monitoring, the learner can check how his plans become actions and, through the introspection made about their achievements, learners can perceive discrepancies between what their goals were and what actually exists. The learner can thereby exercise metacognitive control, reviewing goals, plans to adapt or operations of change (Winne & Nesbit, 2009).

According to Blakey and Spence (2000) the basic metacognitive strategies are a) to know how to relate new information with existing one, b) to know how to select the appropriate thinking strategies and c) to learn to plan, monitor and evaluate the thought processes. The reflection, in a conscious way, about the processes of learning is therefore an essential element to the development of increasingly efficient learners.

To Ertmer and Newby (1996) the *expert learner* is one who is aware of the specific knowledge to reactivate, of the goals they have to achieve and of the strategies they need to achieve them, as well as of this whole process – Figure 2.

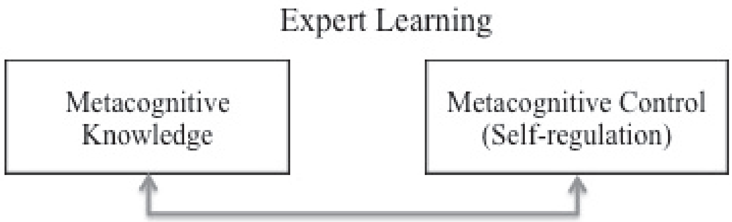

Figure 2. Major components of expert learning (Ertmer& Newby, 1996, pág. 7)

Those learners are considered experts due to the fact that they can incorporate and implement different knowledge to improve their performance.

According to Ertmer and Newby (1996) reflection on the learning process is considered as an essential ingredient to develop more effective learners. In this sense we believe it is important to find strategies that help students monitor their own learning process. This monitoring is a complex process that involves understanding what you're doing, where does that fit into the sequence of the task and also the anticipation and planning of steps to follow. All this happens during the actual act of learning. For Phelp, Hase and Ellis (2001) in the context of rapid transformation, with 'capable' learners, metacognitive strategies provide great advantages and can be considered more important than some skills. In this sense the teacher should provide strategies to help the learner become an "expert learner"

Hacker, Boi & Keener (nd) states that the dynamics at stake between monitoring and control can be illustrated by what we call *calibration*. Different studies on the calibration parameter (Hacker, Bull & Keener, and Stonne, 2000; Hadwin & Webster, 2013; Dinsmore & Parkinson, 2013) define it as "the measure of relationship between the degree of confidence in the performance and accuracy in the same". This means the distance between the level of perception and the actual level of understanding of capacity, competence or preparation at a given area. This implies that the learner make judgments about what content or performances have learned and these judgments are compared to an objective measure of this learning content or performance.

Therefore, calibration plays an important role in the educational context. However, there are some factors that affect this meta-comprehension. An inadequate judgment, for over-confidence or for lack of confidence in the learning, may involve an incorrect monitoring of that process. In turn, it is reflected in the metacognitive control.

Another important concept is also the *self-efficacy.* This concept is related to the belief that everyone has to assess its capabilities to successfully complete a given task. This concept has a huge influence on the way people are dedicated to a particular task, on the persistence to complete it, as well as on the work to be invested. Self-efficacy determines how people feel, think, behave, and motivate themselves. There are numerous studies that show the correlation between the level of self-efficacy and academic performance (Bandura & Locke, 2003; Cascio, Botta & Anzaldi, 2013; Stone, 1993; Taipjutorus, Hansen & Brown, 2012; Zimmerman, 2000b).

An online education system which requires a wide range of students, but also a great deal of persistence and effort to perform learning tasks, knows that the degree of students' self-efficacy is particularly relevant.

Learning in online learning context

In the digital age there are many and varied sources of information that individuals face in their daily life. This reality has implications in education systems and how individuals learn providing a more dynamic learning system, in which its former linearity came to be replaced by a certain way of being and networking learning. This reality brought new scenarios and new ways of looking at the process of learning that are now taken into account.

Cyberculture and the use of technology has enabled new ways to connect with others and with information, with consequences in the methods of formal education. Access to information in different places, led to new challenges and allowed creating knowledge networks. But it is not only in access to knowledge that changes can be found. This way of sharing and living in society also has implications in the way of being and working. Collaborative learning starts having another sense. The "School" won another dimension.

The decrease of spatio-temporal constraints, that the virtual environment brings to the teaching - learning process, make them a more democratic and attractive system for those who depend on training to acquire both the initial level, as well as a continuous education. These are precisely the elements that make these environments successful and where technological, economic, methodological and pedagogical investments are increasing and with greater success.

Technological advances have been giving a new face to distance learning systems. ICTs open new perspectives to facilitate learning. Through the features of virtual learning environments, *virtuality* - eliminating barriers of time and space -, *globality* and the *ubiquity* - the *campus* is always with us.

This new format implies methodological, pedagogical, psychological and even emotional changes with consequent modifications in roles and functions of the actors involved in it.

In the study of Goulão (Goulão, 2000), which had as one of the aims to meet the conceptions of learning in distance education system, a group of higher education students in distance learning were found answers that illustrate this need for self-regulation. An adequate adoption of learning strategies, in particular "the organization / planning" studies and "acquisition of individual work rules", are seen as essential for a successful learning. But the reasons given by the subjects of the sample are not only related to learning strategies, and they also involve personal reasons. For these learners, factors such as self-confidence, persistence / willpower and motivation / desire to learn are also essential for success.

Despite all the investment with the objective of quality education and academic success of our students, there are still some situations that put us questions as teachers and researchers.

Which are the reasons of failure? What is the relationship between the effort that students say they make and their academic success or their ratings? This concern led us to explore this "contradiction" pointed out by students. For this purpose we adapted and used a questionnaire about *study strategies* ($\alpha = .885$). By analyzing the answers we noted that, despite these students present a high degree of self-confidence in their abilities and goals of their learning, this is not always reflected in the use of appropriate strategies in order to achieve them. This is most noticeable in time management, in the use of communication channels available and even in the orientation of the study to more difficult subjects. It is also notorious the near absence of regulation and of setting goals for study sessions (Goulão, 2014).

In online distance education, learners found more flexibility, allowing them to achieve goals that otherwise were unachievable. The acquisitions are located at different levels: concerning their formal knowledge and at the personal level, with the development of their autonomy, their critical thinking and collaborative work. This flexibility of time and space allows better management of their education formation according to their needs. In online distance education environments one of the most important roles of the teacher is as the mediator / facilitator of learning. This means that you as the teacher should aim to provide appropriate educational aid for students to develop their autonomy and their learning construction – Figure 3.

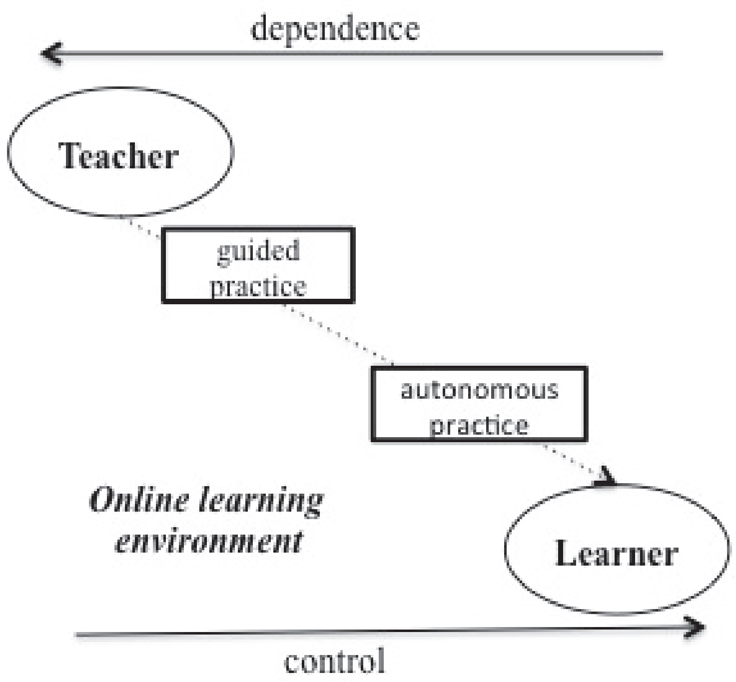

Figure 3. Methodological scenario

Thus, the teacher changes from a carrier of information to a facilitator of the learning processes; from the only source of information to an adviser, mediator, mentor, facilitator, motivator and entertainer of the learning process. Seeks to create a positive environment that gives time to answer, anticipates and resolves questions and problems. He plans and structures contents and activities, using different formats and strategies. He is, therefore, a manager and organizer of information and team work. Because of the specificity of this didactic relationship, learners and teachers, now take roles appropriate to these new demands and to the complexity inherent in virtual environments roles. This leads to the teacher incorporating new skills, without losing his former ones.

Thus, these new learning scenarios lead to a change of attitude and posture relative to this whole process. This change should be taken into account on both sides - learners and teachers. For students, the existence of no direct contact with the teacher and with colleagues can lead to a possible feeling of isolation. Therefore, to ensure that success occurs in these educational environments it is necessary that students are well aware of their individual capabilities to manage their learning, that is, who can use the self-regulated learning strategies.

Learners who know, more appropriately, how to study and how learning occurs, i.e., have better metacognitive knowledge and learn better, when compared with those who have less metacognitive knowledge. It is therefore essential to teach learners about how they learn and identify themselves with the most effective learning strategies, so that they can improve their metacognitive judgments, as well as the self-regulation of their learning.

Material and Methods

Objectives

This study aims to analyze the reflexions made by a set of online students regarding the results obtained in an assessment task and its consequences for the future, in order to consider if the classifications that were obtained were *Higher / Lower / Same* comparing to their forecast.

Design and participants

Data collection was obtained through a question made after the results of their assessment were disclosed. A total of 43 students, in continuous assessment, answered the question, as volunteers.14% was males and 86% were females. The mean age of the participants was 41, ranging from 26 and 57 years old (see Table 2) one student was in his 20s, 21 students were in their 30s, 11 students were in their 40s and 9 students were in their 50s. The median age was 42.

Instruments and procedure

The data was collected in one curricular unit from to the first year, second semester of the degree course in Education. According to the teaching model of the University there are two approaches of assessment that students can select - Continuous Assessment and Final Evaluation (exam). In Continuous Assessment approach there are three evaluation's moments - 2 evaluations online (e-folio A + e-folio B) and 1 presential evaluation. Our research focused on the three moments of evaluation. However, the results we present here concern only two moments of online assessment.

At the beginning of the semester, after students have chosen their evaluation method, a message was placed in the News Forum about the purpose of the research and requesting the participation of the students. Whenever a questionnaire was available for collecting data another message was placed in the forum requesting the response of students. The data collection was done in three stages. Before completing their assessment test (Figure 3 - 1st moment), students were asked to indicate what grade they expected to obtain (Predicted scores). Immediately after finishing their test (Figure 3 – 2nd moment), they were asked again to indicate the grade they expected to obtain (Postdicted score). Finally, after the results came out students were asked to indicate whether their real grades, were higher, lower or equal compared with their prediction (Figure 3 – 3rd moment). Furthermore, they were asked about this and what would be the implications for their study method (Table 3). Our analysis focus was on this last phase.

Table 3. Instructions for data collection

Second part of the question - Data Collection
Was prompted after completing your Test to indicate a rating. Now that you know the classification obtained in this work compare with the ratings assigned to the two previous times. For this comparison we obtained the note in your Test is a) higher / lower / same as you had indicated? b) why? Give at least one reason for this. c) how that fact will influence your study process in the future? Do not forget to click "Next" and then "Submit all and finish". Thank you!

Data analysis

We proceeded to the analysis of participants' responses according to how the questions were asked. It was the purpose of this research to examine the justifications given by the online students regarding the results obtained in the first and second continuos assessment task and how this fact will affect their study process in the future. To analyze their responses, we used content analysis. We used this methodology, in a first phase, in its exploratory approach, seeking emergent information (whith a previous formulation of categories - categorizing *a priori* -) – qualitative dimension. In a second phase, basing our analysis on the occurrences frequency of the categories – qualitative dimension.

The process of forming categories follows the steps provided by Bardin (1977). After selecting the material and the floating reading (phase which establishes contact with the documents to be examined, when the text begins to be understood), exploration was carried out by encoding. The categorization is a procedure that consists of group data considering the common part between them. They are classified by similarity or analogy, at the discretion of the process, resulting in thematic categories. This process should be understood as a form of data reduction, synthesis of communication, highlighting the most important aspects. The categories formulated together a set of elements or log units, grouped according to common characteristics. These, according to Bardin (1977), are defined as "meaning given unit to encode and match the content segment to consider as the base unit in order to categorize and count frequency" (p.104). In our case the categorization was made from the collected data. We used as a criterion to define the dimension the first question - the marks obtained are higher / lower / same. While constructing the categories we had in mind the essential and foreseen criteria in this method:

- *Validity or relevance*: The categories created are meaningful and useful for the proposed work;
- *Completeness and inclusiveness*: It should be possible to include all the units of analysis. There should not exist meaningful data without a classification. It requires the choice of an appropriate keyword and the improved definition of each category;
- *Uniformity*: The entire assembly is structured in a single dimension analysis;
- *Exclusive or mutually exclusive*: Each element can only be classified in only one category;

- *Objectivity, consistency and reliability*: The rating should not be affected by the subjectivity of the investigator and, therefore, may be usable in the same way by various investigators;
- *Productivity*: should offer the possibility of a rich analysis in new cases.

In a pre-analysis level we determined our investigation corpus. The distribution between the first and the second moment was not the same. As we can see in table 4, on the second moment the number of participants increased.

Table 4. Investigation *Corpus*

Moment Gender	1st moment	2nd moment	Total
Male	4	6	10
Female	37	37	74
Total	41	43	84

Since our analysis was about the two moments above, our investigation *corpus* has a total of 84 answers.

In the answers given by the students could be found more than one category or sub-category. For this reason the number of occurrences for each category is greater than the number of participants in the study. Therefore, the occurrence number refers to the number of times that a given register unit arises, regardless of whether the answer is from the same student.

In the Results chapter we are going to present this analysis, which followed the phases and criteria previously described.

Results

First we are going to present the obtained results in the first question – (…) *for this comparison we obtained the note in your assessment is*

a) Higher /lower same as you had indicated?

Table 5. First Question

Moment Type	1st moment	2nd moment	Total
Higher	27	17	44
Lower	8	8	16
Same	6	12	18

The content analysis of the answers given by the students to the question after the results came out (real grades) allowed us to establish the following categories and sub-categories (primary – 1 and secondary - 2), regardless of the dimension related with the first question - Table 6. These are the categories and subcategories common to both online assessment moments (e-folio A and e-folio B).

Table 6. Content analysis results: Categories and sub-categories

Dimensions	Categories	Sub-categorie 1	Sub-categorie 2	Units of register
Higher / Lower / Same	*Causality* Statements concerning the cause of the difference in scores	Extrinsic	System	*Interesting and current topics*
			Teacher	*Monitoring of teacher*
			Task	*Overlap of content*
		Intrinsic	Self	*Motivation* *Self-esteem* *Lack of study* *Misinterpretation of concepts* *Lack of objectivity in the answers*
	Influence Statements concerning the implications of this difference in terms of future studies	*Generics*		*Will positively influence*
		Specifics	Motivation	*Encouragement and Motivation* *Ability to stimulate oneself*
			Method	*Structure the work in function of time* *Direct the effort* *Be more careful when answering*
		No consequences		*I will continue to study the same way*

In the second assessment (e-folio B), another category came up that relates to a more reflexive component of this type of work and to the importance of paying attention to the feedback given by teachers concerning the student's task – Reflexive Category.

The indication of a Higher, Lower or Same classification, comparing the scores obtained with the ones predicted, was not clear. For that reason, the content analysis presented in this paper includes the responses in global terms. The Dimension has not proved to be a suitable descriptor. The answers given by the students, to explain their classifications and implications for their future study, on the one hand, did not have into account whether these where the same, higher, or lower to the classifications they pointed out previously. Students also did not answer to this first question. Future studies of this nature should anticipate this situation by making this a mandatory question and by making it clearer in order to proceed to the next step. The following results refer to the analysis of frequency distribution taking into account the categorie and sub-categories. Table 7 shows the results found in the category Causality.

Table 7. Category *Causality:* Number of occurrences of sub-categories

	Sub-categories 1	Sub-categories 2			N. of occurrences	
					1st moment (e-fólio A)	2nd moment (e-fólio B)
Causality – N = 101 occurrences	*Extrinsic* **Total = 13**	System			2	1
		Teacher			2	1
		Task			2	5
	Intrinsic **Total = 88**	Self	Individual characteristics (Total =28)		12	16
			Performance (Total = 31)	Positive nature	6	4
				Negative nature	13	8
			Organization / Planning (Total = 30)	Positive nature	10	10
				Negative nature	6	4

As it can be seen in Table 7, the highest number of occurrences that justify the classifications obtained is at the level of the **subject himself**. These may refer to more individual characteristics, such as *motivation*, *self-esteem* and *lack of confidence* in the competencies, but also on aspects that may be more controllable by the student. This level involves the way the subject feels within the assessment task, such as an incorrect interpretation of questions, or a difficulty in understanding some questions. Finally, we find the issues related to the preparation for the assessment task. These refer to the organization and planning of the study itself.

We turn now to the presentation of the results concerning the influence for future study situations. - Table 8

Table 8. Category *Influence*: Nº of occurrences of sub-categories

	Sub-categories 1	Sub-categories 2		N. of occurrences	
				1st moment (e-fólio A)	2nd moment (e-fólio B)
Influence –N= 78 occurrences	Generics (Total = 15)			9	6
	Specifics Total = 59	Motivation (Total = 25)		10	15
		Method (Total=34)	Performance	8	4
			Organization	9	13
	No consequences Total = 4			1	3

The largest number of occurrences indicates that the influence will be felt more deeply at the level of motivation and method of work. This is particularly true in regards to issues relating to the method of organizing tasks in either study, or in they performance in the next assessment task.

Table 9. *Reflexive Category*: Nº of occurrences.

	Category		Units of register	N. of occurrences
e-fólio B	Reflexive	Answers related to: a) The influence of this type of survey on the reflection about study methods; b) Teacher's feedback purpose in future works.	*- This type of survey does reflect on the consequent results;* *- Correction criteria are important to understand the failures* *- Reflection on the expected rating and the received rating guides for the future*	6

Discussion

The purpose of this study was to analyze the reflexions made by a set of online students regarding the results obtained in an assessment task and its consequences for the future.The results did not fully meet our expectations. That is, we expected to find differences in the reflections of the students taking into account the difference between self-reported rating and the actual classification. One possible explanation may be due to the fact that most students have located the dimension "Higher" followed by dimension "Same".

Because we consider this competence extremely important, our bet to the future is to find strategies that can promote the ability of online students become better at self-regulating their learning. For this is being developed a program to promote self-regulation in higher education online.

Responses determined through content analysis point to an awareness of the importance of student role in the learning process. This consciousness goes beyond the simple explanation of why they have obtained certain result. This stance goes beyond simply knowing of facts and operating procedures. According to Ertmer and Newby (1996), the competence to monitor and self-regulate learning goes beyond the knowledge of what is important, especially how to apply this knowledge into concrete actions. For this, it is important that students are able to reflect on their learning experiences. The importance of this reflection was found on our results, particularly in the second assessment.

There are some suggestions for further research. First, research should not be conducted employing a sample from a less homogeneous population. We seek to extend the investigation to other years and other scientific areas. Secondly, explorer of a more consistently reflections depending on the size Higher / Lower / Same. Finally, because we consider this competence extremely important to our future, our bet is to find strategies that can promote the ability of online students become well self regulatory their learning. For this, it is being developed a program, which is in the experimental phase, to promote self-regulation in higher education online, as we said earlier.

Conclusions

In this paper, we set out to find out and work on the reflections that a group of online learning students has made about their performance in two assessment tasks. In a first analysis of the responses we observed that these reflections involve mainly factors related to the students or factors that they can control.

The analysis of the answers seems to indicate an emphasis on the concern with issues related to organization and planning of the study. This is evident in both the causes and the conditions to be considered in a future study. However, reading these results should be done in a careful manner and taking into account that the students participated in this study voluntarily and that the majority considered to have a good rating, taking as reference the statement given in the previous phase of the study.

From our point of view is important to know the aspects that are taken into account and valued by students to have a good performance. These elements allow us to organize tasks and outline strategies to help students find their own plan of action for monitoring and self-regulation of learning, becoming increasingly autonomous and thereby achieving a deeper level of learning. The knowledge that each person has in dealing with learning activities becomes a powerful tool nowadays (Bjork, Dunlosky & Kornell, 2013). The understanding of learning activities and associated processes promotes understanding, retention and transfer of learning. As discussed in previous work: to develop self-regulatory competence of students is not only very important to help them achieve success now, but also to ensure future successes. Actions relating to the control of performance have a critical role in the self-regulatory process leading to a monitoring process of learning by the students.

This action control allows them to not only detect the weaknesses of the learning process, but also alert to the effectiveness of learning strategies that are being used. (Goulão & Cerezo, 2015, p. 1907).

Distance online education puts the emphasis on the autonomy of their students. Therefore, it is necessary that students are holders of skills that enable them to analyze, understand, and evaluate their learning process, aiming at a significant learning.

Therefore, it is necessary that they are holders of skills that enable them to analyze, understand and evaluate their learning process, aiming at a significant learning.

References

Azevedo, R. & Cromley, J.G., (2004). Does training on self–regulated learning facilitate student's learning with hypermedia? *Journal of Educational Psychology*, 96(3), 523-535.

Bandura, A. & Locke, E. (2003). Negative self-efficacy and goal effects revisited. *Journ al of Applied Psychology*, 88 (1), 87 – 99.

Bjork, R.A., Dunlosky, J. & Kornell, N. (2013). Self-Regulated Learning: Beliefs, Techniques and Illusions. *Annual Review of Psychology*, 64,417–444.

Blakey, E. & Spence, S. (2000). Developing metacognition. Syracuse, NY: *ERIC Clearinghouse on Information Resources*. Retrieved from http://ericae.net/edo/ED327218.htm.

Bol, L & Garner, J.K. (2011). Challenges in supporting self-regulation in distance education environments. *Journal Computer High Education,* 23, 104 – 123.

Cascio M., Botta V. & Anzaldi V. (2013). The role of self-efficacy and internal locus of control in online learning.*Journal of e-Learning and Knowledge Society*, 9 (3), 95-106.

Ertmer, P. A. & Newby, T. J. (1996), the expert learner: Strategic, self-regulated and reflective. *Instructional Science*, 24, 1-24.

Goulão, Mª F. (2000). O ensino a distância e a formação de adultos. *Revista Galego-Portuguesa de Psicoloxia e Educación*, 6 (4),657-665.

Goulão, Mª F. (2014).The relationship of e-learner's with studies strategies to support learning.*Procedia - Social and Behavioral Sciences* 116, 362 – 367.

Goulão, Mª F. & Cerezo, R. (2015).Learner autonomy and self-regulation in eLearning.*Procedia - Social and Behavioral Sciences* ,174, 1900 – 1907.

Hacker, D.J., Dunlosky, J. & Bjork, R., (2009) Metacognition in Education: A focus on Calibration. In Dunlosky, J. & Bjork, R. (Eds.), *Handbook of Memory and Metacognition* (pp.1-49). Mahwah, NJ: Lawrence Erlbaum Associates.

Leclercq, D. & Denis, B. (1995). Autoformation & Hypermédias: Qu'est-cequ'unbon auto-apprenant? in *Pratiques d'autoformationet d'aide à l'autoformation*, Actas do Deuxièmecolloqueeuropéensurl'autoformation, USTL / CUEEP, pp.155 – 161.

Nakata, Y. (2014). Self-regulation: Why is it important for promoting learner autonomy in the school context? *Studies in Self-Access Learning Journal,* 5(4), 342-356.

Nielsen, H. (2012). E-learning and the dilemma of learner autonomy: A case study of first year university of Arabic. *OrientaliaSuecana LXI Suppl.*, 89 – 105.

Phelp, R., Ellis, A. & Hase, S. (2001, December). The role of metacognitive and reflective learning process in developing capable computer users. In in G Kennedy, M Keppell, C McNaught& T Petrovic (Eds), *Meeting at the crossroads: proceedings of the 18th Annual Conference of the Australasian Society forComputers in Learning in Tertiary Education (ASCILITE)* (pp. 481-490). University of Melbourne, Biomedical Multimedia Unit, University of Melbourne, Melbourne, Vic.

Saks, K & Leijen, A. (2013). Distinguishing self-directed and self-regulated learning and measuring them in the e-learning context. *Procedia – Social Behavioral Sciences*, 1-9.

Serra, M.J. & Metalfe, J. (2009). Effective Implementation of Metacognition. In Hacker, D. J. Dunlosky,J. &Graesser,A.C. (Eds.). *Handbook of Metacognition in Education* (pp.278-298). New York: Routledge.

Stone, D. (1993). Overconfidence in Initial Self-Efficacy Judgments: Effects onDecision Processes and Performance. *Organizational Behavior and Human Decision Processes*, 59 (3), 452-474.

Taipjutorus, W., Hansen, S., & Brown, M. (2012). Investigating a Relationship between Learner Control and Self-efficacy in an Online Learning Environment. *Journal of Open, Flexible, and Distance Learning*, 16(1), 56 – 69.

Winne,P.H. & Nesbit, J.C.(2009). Supporting Self-Regulated Learning with Cognitive Tools. In Hacker, D., Dunlosky, J. & Graesser, A. (Eds). *Handbook of Metacognition in Education* (pp.259-277). New Yok: Routledge.

Zimmerman (2000[a]). Attainingself-regulation: A social cognitive perspective. In Boekaerts, M., Pintrich, P.R. & Zinder, M. (Eds), *HandbookofSel-Regulation* (pp.13-29). San Diego, CA :AcademicPress.

Zimmerman, B. (2000[b]). Self-Efficacy: An Essential Motive to Learn. *Contemporary Educational Psychology*, 25, 82–91.

Zimmerman, B. (1998). Academic studying and the development of personal skill: a self-regulatory perspective. *Educational Psychologist*, 33(2/3), 73-86.

Chapter 7

Reliability of mixed-format exams in higher education

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Abstract: In higher education courses, instructors often use mixed-format exams composed of several types of questions such as essays, short answer, problem solving, or multiple choice to evaluate student performance. It is important to discriminate reliably among students according to their performance on final examinations. The lower the reliability of student exam scores, the greater the error associated with making decisions based on them. Why then have we found no previous studies of reliability for the mixed-format exam, one of the most common types of evaluation? We review the literature on reliability and draw several conclusions that any researcher should consider when studying exam score reliability. We investigated the reliability of student scores on 12 official mixed-format final exams used in 22 classes with 1012 students in six undergraduate courses taught by five professors in three fields of business: finance, accounting, and statistics. We focussed on estimating internal consistency reliability, which is essentially a measure of the reproducibility of test scores. Using coefficient omega, the most appropriate measure for assessing reliability for mixed-format exams, we found that in these 22 classes score reliability averaged .85, with over 90% of the classes with reliabilities exceeding .80. These reliabilities are very high, comparable with those reported for professionally developed standardized tests and better than those reported recently for single-format multiple-choice exams in higher education.

Keywords: Reliability; mixed-format exams; coefficient alpha; coefficient omega; higher education; internal consistency reliability

Introduction

Professors in higher education employ a variety of different types of exams. Single-format exams have only one type of question on the exam – essay, short answer, problem solving, and multiple choice questions (MCQ). Although some professors have, in recent years, increasingly resorted to the use of MCQ tests in response to dramatic rises in class sizes (Ackerman *et al.*, 2010; Biggs, 2003; DiBattista & Kurzawa, 2011), many eschew the use of MCQ exams. Instead, they administer one of the most common types of exam used in academe, mixed-format exams, which are composed of a mixture of question types with different values assigned to each question (Qualls, 1995). In fact, mixed-format exams are becoming increasingly popular even on standardized tests such as the SAT (Cao, 2008, p.18).

Mixed-format exams have the singular disadvantage of requiring an excessively long time to mark as do essay and problem solving exams (Lee *et al.*, 2014). Nevertheless, they offer distinct advantages over other types of exams including ease of construction, reputedly high content validity, and the ability to assess problem solving and higher-order reasoning skills. As well, by including different types of questions on an examination, professors can minimize the weaknesses inherent in any particular single type of question. For example, adding essay or short answer questions to an MCQ exam might offer a better method of assessing higher-order reasoning knowledge while perhaps also retaining some of the advantages conferred by posing many multiple choice questions (reliability of exam scores generally increases as the number of questions posed on an exam goes up). Given their significance in determining student success or failure, examining the reliability of student scores on mixed-format examinations, as with any type of exam, is of considerable importance. This is the focus of the present study.

We could find no previous assessments of the reliability of mixed-format exams. Perhaps this is not surprising given that the theoretical techniques for accurately estimating the reliability of student scores for such exams have been developed only recently (Dunn *et al.*, 2014). As well, Cox (1967) noted that "although examining is an important and time-consuming occupation, very few of those who are actively engaged in it regard it as a field for experiment and research, or if they do, they keep their findings very much to themselves".

The purpose of this chapter is fourfold. The primary goal is to fill this gap in previous research by estimating empirically the reliability of student scores on mixed-format exams in higher education in a variety of classes, courses, and subject areas in higher education as well as with different professors, students, and final exams. A second goal is to review the literature on reliability to ascertain which of the many types of reliability is most appropriate for this task. The third goal is to review the literature on internal consistency reliability, the most appropriate type of reliability for assessing exam score reliability, to determine which of the many estimates of such reliability is most appropriate for estimating empirically the reliability of student scores on mixed-format exams in higher education. The fourth and final goal is to compare the reliabilities found in our empirical studies for mixed-format exams in higher education with those found by others for such common single-format exams as MCQ only, essay only, and problem-solving only exams.

To guide the reader, we first sketch the contents of the remaining sections of this chapter. In the next section (to address the second and third goals of this chapter), we review pertinent literature on the issue of reliability and exams in higher education starting with a discussion of what reliability is in the context of examinations. We then introduce three major types of reliability (stability over time, inter-marker, and internal consistency) and discuss the reasons why internal consistency should be the focus of attention when assessing exam score reliability. We provide a rationale for using coefficient omega, and not the more commonly used coefficient alpha, to estimate internal consistency reliability of mixed-format exams. We review recent literature emphasizing the importance of reporting confidence intervals for reliability estimates and for establishing standards to be met by exam score reliabilities in higher education courses. We conclude this review of the literature by pointing out the importance of considering three types or categories of academic decisions that are made by professors about students on the basis of their performance (a) on an exam, (b) in a course, and (c) in a program of study. We argue that the reliabilities reported in our study are pertinent only to the making of academic decisions about individual students based on their performance on that exam (e.g., their grade on that exam). The higher the reliability of exam scores the lower the error associated with making academic decisions based on those scores. However, our reliabilities are not directly relevant to the making of academic decisions based on student performance in the entire course including midterms, assignments, projects, and reports (e.g., their grade in that course), or decisions based on a student's performance in all courses in an academic program of study (e.g., the awarding of first or second class honours).

After this review of the literature, the next two sections describe the method and results of our empirical study of 12 final exams used in 22 classes of students taking 6 different courses in three fields within business: statistics, accounting, and finance (to address the first goal of this chapter). The final sections of our chapter discuss the results of our empirical studies, draw conclusions about the use of mixed-format exams in higher education, and provide recommendations and a discussion of future work. Included here is a comparison of the reliabilities we have found for mixed-format exams with those obtained by others for MCQ only, essay only, and problem-solving only exams (to address the fourth goal of this chapter).

Review of the Literature on Reliability

Reliability of exam scores

To be useful, student exam scores must be reliable (Brennan, 2001; Meadows & Billington, 2005; Wilmut *et al.*, 1996). According to Dracup (1997, p. 691), "The greater the reliability of an assessment, the more certain we can be that observed differences between the individuals on the assessment are the result of real differences between the individuals on whatever the assessment is measuring rather than the result of random error." Error associated with student scores on an exam generally decreases as reliability increases (Tavakol & Dennick, 2011).

Unfortunately, both researchers and practitioners (that is, professors and instructors in higher education) often misunderstand reliability (Cizek, 2012; Cizek *et al.*, 2008; Fan & Thompson, 2001; Frisbie, 1988; Thompson, 2003; Thompson & Vacha-Hasse, 2000; Whittington, 1998). Many, for example, mistakenly assume reliability to be an inherent property of the test or exam itself. The falsity of such a belief is immediately apparent on reflecting that a given exam will take on as many different reliability values as one has classes of students taking the same exam. Just because a test has high reliability for one class of students does not automatically imply that it will have exactly the same value, or even a similar value, for all other classes taking the same exam, though one would expect the reliability to be relatively similar for students at the same academic level and taking the same course. As Frisbie (1988, p. 25) asserted some time ago "reliability is a property of a set of test scores, not a property of the test itself." More recently, many others have emphasized the importance of this same issue (e.g., Crocker & Algina, 2008; Fan & Thompson, 2001; Thompson, 1994, 2003).

However, "examination marks are not perfectly reliable, that is to say that if the assessment is repeated in some way, the candidate will generally receive a second mark which is different from the first" (Hill, 1978, p. 186). In higher education, it is important to discriminate reliably among students according to their final examination marks (Dracup, 1997; Munro *et al.*, 2005). The lower the reliability of student exam scores, the greater the error associated with making decisions based on those scores (Crocker & Algina, 2008; Nunnally & Bernstein, 1994). Furthermore, reliability of test scores, in general, is of central importance (Henchy, 2013; Jones & Thissen, 2007). Wilkinson and the APA Task Force on Statistical Inference (1999) criticized researchers for not assessing the reliability of the test scores used in their studies. Editors of some journals have argued in a similar vein (Fan & Thompson, 2001). The same criticism can be made of classroom exams.

Types of reliability

Classical test theory, to which we will restrict our attention in the remainder of the present chapter, is well known to be more than satisfactory when considering reliability issues for classroom exams (Nunnally & Bernstein, 1994). As Burton (2005, pp. 71 and 66) states, the much more complex alternative to classical test theory, *item response theory*, “may seem attractive because it is sophisticated and often carries the label of ‘modern’, but academic tests do not typically have appropriate characteristics.” In fact, it is a myth and not to be believed that “item response theory (including the simplest version, the Rasch model) is superior to classical test theory for analysing items in academic tests.”

In classical test theory, reliability is generally assessable in three forms: stability over time reliability, inter-marker reliability, and internal consistency reliability (Henson, 2001; Nunnally & Bernstein, 1994). For *stability over time reliability* (Crocker & Algina, 2008, pp. 133-134), the focus is usually on assessing how student scores on an exam change over some period of time, primarily because of temporary changes in the student. Stability over time is typically estimated by *test-retest reliability*, the correlation between student scores on the same exam administered twice. However, test-retest reliability is of little concern here given that student exam scores on any repeated administrations of exactly the same exam would have to be suspect. Moreover, the recognition of test-retest reliability as a weak form of reliability is widespread (Morley, 2014, p. 130; Nunnally & Bernstein, 1994, p. 255). Consequently, we are not concerned with this form of reliability.

Inter-marker reliability, a form of inter-rater reliability, is typically estimated by the correlation among markers in the grades awarded to students for a common exam. However, Krippendorff (2004) and Morley (2014) reviewed the strengths and weaknesses of many other measures of inter-rater reliability that have also been proposed. This form of reliability is focussed primarily on the error introduced into assessments of student exam performance by variation in how different markers score the same student exams (Crocker & Algina, 2008, p. 143). Many researchers have investigated the inter-marker reliability of single-format classroom exams in higher education (e.g., Dracup, 1997; Hill, 1978; Newstead, 2002). However, inter-marker reliability was not of interest in the present study for two reasons. First, in many higher education institutions, having multiple markers mark each exam in a course occurs rarely and is economically impractical given the large class sizes typical in this same region. Second, and arguably more importantly, however, Morley (2014, pp. 128-129) convincingly makes the case that “internal consistency is appropriate when we want to make statements about the respondent” (the student, in our case) whereas other types of reliability are appropriate for other purposes (Ebel, 1965; Morley, 2014).

The third form of reliability, *internal consistency reliability*, estimates the correlation between a test and an alternative version of the same test of the same length, having randomly selected questions (Henson, 2001). As Nunnally & Bernstein (1994) have stated, internal consistency reliability is a measure of how well the questions posed on an exam measure the same construct, that is, the degree to which all the questions measure the knowledge or skills learned in an academic course. It depends to a degree on the average inter-correlation among the student responses to the questions posed on an exam. Thus, one would expect student scores on different questions on a given exam to be correlated.

We focused on estimating only this type of reliability, first, because it can be estimated with the single administration of a test. Second, being the most commonly reported measure of reliability (Hogan *et al.*, 2000; Padilla *et al.*, 2012; Thompson, 1999), it is easily understood. Third, the other two reliability estimates were of little importance in our present studies, test-retest because it is widely recognized as a weak form of reliability (Krippendorff, 2004, p. 216) and inter-marker because in many institutions only a single individual marks each final exam. Furthermore, as Morley (2014, p. 128) pointed out "The critical difference between internal consistency reliability and inter-rater [i.e., inter-marker] reliability is that, with the former, one is attempting to make a statement about the test-taker, and, with the latter, one is attempting to make a statement about some object of judgement such as a professor."

Measurement models underlying various estimates of internal consistency reliability

Many methods have been used to estimate internal consistency reliability (Nunnally & Bernstein, 1994). However, *Cronbach's coefficient alpha* (α), which is based on the *essentially tau-equivalent measurement model* in classical test theory (Graham 2006; Lord & Novick, 1968; Sijtsma, 2009), is the most commonly reported measure of internal-consistency reliability (Hogan *et al.*, 2000; Miller, 1995; Padilla *et al.*, 2012; Thompson, 2003). For exams composed of only one type of question and in which all questions are of equal value, the assumptions underlying the use of this model are frequently met, and coefficient alpha provides an appropriate estimate of exam score reliability (Nunnally & Bernstein, 1994). However, in many situations, alpha often underestimates actual reliability because the assumptions underlying the use of this measure are frequently violated in mixed-format tests (Lord & Novick, 1968; Miller, 1995; Qualls, 1995). Two factors, both characteristic of mixed-format exams, can contribute to these violations: questions on the same exam that either vary in the marks allotted and/or are of more than one type or format.

The *congeneric model*, a more general variation of classical test theory than the essentially tau-equivalent model underlying coefficient alpha, permits both questions of various types and questions of varying mark allocations on the same exam (Qualls, 1995). Many alternative measures of congeneric reliability have been proposed, such as the *greatest lower bound* (*glb*) and *coefficient omega* (ω) (e.g., Feldt, 2002; Feldt & Brennan, 1989; Graham, 2006; Sijtsma, 2009). Though there has been an extended debate on which measure is most appropriate to use, some consensus has emerged that coefficient omega is the best (e.g., Dunn *et al.*, 2014; Revelle & Zinbarg; 2009).

We argue, therefore, that *coefficient omega*, which is based on the congeneric measurement model, provides a more accurate and more appropriate estimate of actual reliability for mixed-format classroom exams than other models (e.g., Dunn *et al.*, 2014; Feldt & Charter, 2003; Peters, 2014; Schmitt, 1996). The arguments favouring coefficient omega include the ability to compute confidence intervals (to date no confidence interval equations have been derived for the *glb* given its mathematical intractability). In addition, the *glb* is not the greatest lower bound for the reliability of test scores, despite the name (Revelle & Zinbarg, 2009). Hence, coefficient omega should be used for tests that use multiple-item formats or a range of varying score values for different exam questions, as they do for the mixed-format exams in the present study (Dunn *et al.*, 2014; Padilla & Divers, 2013a, 2013b; Qualls, 1995).

The need for confidence intervals when reporting reliability estimates

In recent years, many authors have argued persuasively for the importance of providing confidence intervals for reliabilities (e.g., Dunn *et al.*, 2014; Fan & Thompson, 2001; Wilkinson *et al.*, 1999). These arguments parallel those made by others for reporting confidence intervals for analysis of variance and regression estimates (e.g., Cumming & Finch, 2001; Smithson, 2001). We follow their advice later in this paper when reporting reliabilities for student scores on exams in various courses. The primary bases for this recommendation (Cumming & Finch, 2001; Dunn *et al.*, 2014) are that confidence intervals (1) are directly interpretable, (2) directly estimate the range within which one can reasonably expect the true reliability or reliability for the target population to fall, (3) are directly associated with familiar hypothesis tests, and (4) inform readers about the precision of reliability estimates. In effect, estimates of score reliabilities are affected by sampling error variance (Fan & Thompson, 2001).

Types of academic decisions and reliability

We believe that it is useful here to distinguish among three types or levels of academic decisions about individual students that we will call exam, course, and program decisions with each type of decision corresponding to a different standard or target for score reliability. Exam decisions are those made by instructors on the basis of the mark attained by a student on the final exam in a given course. For example, in the business statistics course investigated in the present study, the mark achieved by a student on the exam (measured in per cent) determines the grade awarded on that exam (e.g., A+, A, A-, B+, …). An important aspect of this grading decision, often singled out for attention by educational researchers, is the decision of whether or not to fail a student on the exam. The internal consistency reliability of student exam scores, such as those reported in the present study, directly impact the quality of such decisions. High exam score reliability implies low error, improving the quality of instructor decisions made on the basis of such student marks in the specific course of concern.

Instructors and administrators also make course decisions, or decisions about students based on their performance in all aspects of a given course. For example, in some courses, instructors may allocate the total marks in a course to student performance on some combination of the marks achieved on the final exam, midterm exams, assignments, quizzes, project reports, and class presentations. Often the grade awarded in a course depends to a large degree on the performance of a student on the final exam. Exam reliability would then become a major, but not the sole, determinant of course grade reliability. Course reliability would normally be higher than the reliability of the final exam alone because of the additional factors taken into account such as midterms, quizzes, and assignment marks (Nunnally & Bernstein, 1994). However, we do not address the question of course grade reliability in the present chapter.

Finally, some decisions made by instructors and administrators are based on a student's performance in more than one course, which we shall call program decisions. For example, the awarding of some scholarships or admission to graduate school might be based on a student's performance in a collection of courses. As Draper

(1997) has shown for essay exams in psychology, exam/course score reliability might be quite low for many courses but when decisions affecting a student are based on the student's performance in many courses, (program) reliability can become very, very high (α = .95). Thus, there is little error typically associated with making program-related academic decisions such as which individual students should be awarded first or second class honours in psychology (or, for that matter, in any other discipline).

In the present chapter, our sole focus is on exam score reliability (and not at all on course grade reliability or on program performance reliability). Instructor decisions, such as the grade assigned by the instructor to a student based on their performance on the course final exam, depend on the reliability of student exam scores in that class. In contrast, instructor decisions about course performance, such as the overall grade assigned to each student based on their performance on all graded aspects of the course (such as assignments, midterms, final exams, and reports) depend upon the reliability of marks achieved by students on all required components of the course. Similarly, instructor decisions about student performance in a program of study depend upon the reliability of (average) student performance on all courses taken within the academic program. In the present chapter, we do not investigate either course grade reliability or program performance reliability. Therefore, the exam score reliabilities reported herein have no direct bearing on instructor course grade decisions or program performance decisions.

The need for establishing reliability standards

What reliability (estimated by alpha or omega) should we expect of any acceptable exam used to assess student performance in a course in higher education? According to Schmitt (1996, p. 353), "There is no sacred level of acceptable or unacceptable level of alpha. In some cases, measures with (by conventional standards) low levels of alpha may still be quite useful." This is as true of coefficient omega as it is of coefficient alpha; both are comparable measures of reliability. Regardless of whether or not a standard is adopted, the higher the reliability, the better it is for making decisions about students.

However, as Fan & Thompson (2001) argue, a standard for reliability should always be specified and a rationale provided for that value (for a contrary opinion, see Schmitt, 1996). As Nunnally & Bernstein (1994) assert, the standard or target reliability should depend upon the uses to which test scores are to be put. For exploratory work or less important decisions, low reliabilities are satisfactory. However, when important decisions are to be made about individual test takers, higher reliabilities are required to minimize error. Instructors and administrators in higher education often make decisions on students based on their academic performance but these decisions vary in their purpose and importance.

We argue that exam score reliability should ideally exceed .70 for the courses in finance, statistics, and accounting examined in the present study, with the caveat that even higher reliabilities than .80 are preferable. Our rationale for adopting this standard is based on three considerations. First, the standard set for the clinical use of psychological, medical, or educational high-stakes tests (such as the SAT or GRE) is generally considered to be at least .70 (Considine *et al.*, 2005; Schmitt, 1996) and by some to be at least .80 (DiBattista & Kurzawa, 2011; Nunnally & Bernstein, 1994). Such high reliabilities minimize errors when important psychological, medical, or educational judgments or decisions are made affecting individuals (such as admission to graduate school). Given the importance for individual students in higher education of minimizing errors when academic judgments or decisions are based on their performance on some low-stakes examination in a course, setting a high standard seems most appropriate. Second, given that all classes tested in the present study were in strongly quantitative areas, we expected reliabilities to be relatively high. Reliability for student exam scores in quantitative courses is known to be generally higher than that for non-quantitative courses (e.g., Dracup, 1997; Meadows & Billington, 2005). For non-quantitative exams, such as essay-only exams in psychology, lower standards are undoubtedly more realistic. Lower standards for such courses would necessarily be at the cost of greater error when judgments or decisions are made about students based on their performance in such courses. Third, considering the importance of minimizing errors in individual students' exam grades, we felt that a high minimum standard should be set for the reliability expected of student exam scores in these quantitative courses. To be on the conservative side, we set the minimum standard to be exceeded for the reliability of exam scores in a given class in finance, statistics, or accounting to be at least .70 and preferably .80 or higher.

However, (course) decisions on students are often based not just on their performance on a single final exam but on assignments, midterms, projects, and presentations in the same course as well. Such additional measures of student performance generally increase reliability (Nunnally & Bernstein, 1994). Thus, reliability of student scores on a single final exam undoubtedly underestimates the reliability of student grades assigned for all components of a course. Given the added importance of making sound course decisions on students, we believe that course score reliabilities should be at least .80 to .85 and even higher for quantitative courses such as ours. Furthermore, (program) decisions about students are often made on the basis of performance in many different courses with different professors, fields, class sizes, and time periods. Program decisions include the most important decisions that are made on the basis of student performance in multiple courses such as scholarship awards and admittance to graduate school. Internal consistency reliabilities based on a collection or program of courses can easily exceed .95 even when the reliability of any single course is much lower (e.g., Dracup, 1997). We believe the target or standard for program reliability should be set equal to that stipulated by Nunnally & Bernstein (1994) and Henson (2001, p. 181) of .90 to .95 for standardized tests used in making important clinical decisions about individual patients or clients. We applied these standards for reliability estimates for final exams in the empirical studies described next.

Averaging reliability estimates

There has been much controversy in the literature on reliability as to which of the many alternative methods that have been proposed for averaging reliabilities (or correlations) is best to use (e.g., Alexander, 1990; Corey, Dunlap, & Burke, 1998; Dunlap, Silver, & Bittner, 1986; Hunter & Schmidt, 1990; Silver & Dunlap, 1987). To average reliabilities in our study, we used two of the methods described by Feldt and Charter (2006). In their Monte Carlo study, they examined six different approaches to averaging internal consistency reliabilities that had been advocated by previous researchers. In their study, all approaches generated virtually identical averages. Clearly, the method used to average reliabilities has little impact. To be conservative, we used their approaches #1 (the simple weighted by class size average) and #3 (the r-to-z and z-to-r transformations weighted by class size) to average reliabilities but expected no differences between them for our data.

Literature review summary

In summary, our review of the literature led us to make six conclusions. First, internal consistency reliability is the most appropriate form of reliability to estimate for exams in higher education given that our focus is on student test takers. Second, coefficient omega is the most appropriate measure to estimate when concerned with the internal consistency reliability of mixed-format exams, not the much more commonly used coefficient alpha. Third, confidence intervals should always be reported for estimates of exam score reliability. Fourth, a target or standard should always be specified, and a rationale provided, for the reliability of exams expected in the higher education courses being studied (for the mixed-format exams in the quantitative business courses in our study, our target was to achieve score reliabilities of at least .70 and preferably over .80). Fifth, the exam score reliabilities for the classes tested in our study and for the majority of reliabilities reported in the literature are appropriate when considering the error associated with academic decisions based strictly on a student's performance on that exam (e.g., pass/fail decisions). Sixth, the method used for averaging reliabilities is probably unimportant, given that all alternative methods appear to generate virtually identical means. Nevertheless, to be conservative, we elected to use two alternative methods of averaging reliabilities (methods #1 and #3 in Feldt & Charter, 2006). We took these six conclusions as prescriptions to follow in the conduct of our empirical studies of the reliability of mixed-format exams in higher education courses that are described in the next two sections of this chapter.

Method

In our study, we investigated over the past several years six undergraduate courses offered at a Canadian university from three different fields in business: statistics (S), finance (F), and accounting (A). All classes were one-term (typically four, but sometimes two, months in duration), 39 lecture-hour courses (see Table 1). Classes S1 to S15, F1, and F2 were taught in the second year; F2, F3, A1, and A2 were taught in the third year; and A3 was taught to graduating students in their fourth and final year of studies. The statistics and finance courses were introductory level, whereas the accounting courses were either at the intermediate or advanced levels. Student performance on all exams was graded out of 100%. A single marker, who was the course instructor in all cases, graded each exam (customary in many institutions). In all these courses, professors administered mixed-format exams that varied between 2.0 and 3.0 hrs in length. These 22 classes comprised a total of 1,012 students. Roughly 55% were females and 45% males. One male and four female instructors, ranging from lecturers to full professors, took part in our study. A total of 12 different exams were used. For each exam, student scores on each part of each question that had been separately marked on the original exam were entered in an SPSS spreadsheet. Reliabilities were then computed for each class.

In all 22 classes, final exam marks only accounted for 40% to 55% of the total marks assigned in a given course. In all cases, course marks were based on a variety of course components including final exams, midterm exams, and assignments. Student performances on components other than the final exam were not available for the purposes of the present study.

Table 1: Marks allotted on each separately markable question on each exam in our study

	Exam Description						Question Types on Exam			
Exam	**Field**	**Course**	**Year**	**t**	**q**	**m**	**MCQ**	**SA**	**PS**	**Essay**
1	Fin	Intro 1	2	180	37	106	2 2 2 2 2 2 2 2 2 2 2 2	3 3 3 3 3	1 1 1 2 2 2 2 2 2 2 3 3 3 4 5 5 6 6 6 9	
2	Fin	Intro 2	3	180	47	106	1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5	3 3 3 3	1 1 1 1 1 1 1 1 1.5 1.5 1.5 1.5 1.5 1.5 2 2 2 2 3 3 3 3 3 3 4 4 6 8 8	
3	Acc	Int 1	3	180	36	100	.5 .5 .5 .5	1 2 2 3 5 5	1 1 1 1 1 1 1 1.5 1.5 2 2 2 2 2 3 3 3 3.5 4 4.5 5 5 6 6 8 9	
4	Acc	Int 2	3	180	33	100		1 1 1 2	1 1 1 1 1 1 1 1 1 1 1 1.5 2 2 2 2 2 3 3 3 3 3 3 3 5 5.5 9.5 12 19.5	
5	Acc	Topics	4	150	20	99		2 2 2.5 2.5 3 4 4 6 7 10	2 3 6 7 8 30 (5 parts)	
6	Stats	Intro	2	180	15	100		2 2 2 4	2 3 4 5 6 8 8 10 12 14	18
7	Stats	Intro	2	180	21	110	2 2 2 2 2 2 2 2 2 2		2 2 2 2 2 5 5 10 20 20 20	
8	Stats	Intro	2	180	27	100	1 1 1 1 1 1 1 1 1 1	2 2 2 2 2 2 3	2 3 3 4 5 6 10 12 15 15	
9	Stats	Intro	2	150	31	100				
10	Stats	Intro	2	120	13	100		2 4 4 6	2 5 5 6 8 10 10 18 20	
11	Stats	Intro	2	120	12	100		4	3 3 4 5 5 6 6 8 18 18	20
12	Stats	Intro	2	120	30	100				

Note: t = duration of the exam in minutes*; q* = number of questions on exam*; m* = total marks on exam; *MCQ* = multiple choice questions; *SA* = short answer questions; *PS* = problem solving questions; *Essay* = long answer essay questions; Fin = course in finance; Acc = course in accounting; Stats = course in statistics, Intro 1 = first part of the introductory course (in finance), Intro 2 = second part of the introductory course (in finance), Intro = introductory course (in statistics), Int 1 = first part of the intermediate course (in accounting), Int 2 = second part of the intermediate course (in accounting), and Topics = special topics in accounting.

In most cases, the professor teaching a class made up the exam for that class (and, in many cases, the same exam was administered to several classes taking the same course in the same academic term). In one case, however, one of the teaching instructors used the exam made up by a more senior professor who was teaching the same course in the same academic term (see Table 2 which shows that in statistics class S4 professor d used professor c’s final exam #6). Professors making up any of the 12 final exams in the present study were free to make up and use any questions they wished to without constraint (other than their own common sense). In no case were different exams administered to students taking the same course, albeit in different classes, in the same academic term. All classes that administered the same exam also covered exactly the same subject material in the course. However, all professors or instructors were free to teach the assigned or agreed upon course material in whatever way they wished. The course material covered on any specific exam within a given course could, however, change from one academic term to another, though such changes were typically minimal during the period of this study.

The composition of mixed-format exams varied considerably from one exam to another. Table 1 provides a detailed description of the questions posed on each of the 12 exams considered in our study as well as the number and type of questions posed and the maximum marks allotted to each of them. The four types of questions employed on these 12 exams included essay, problem solving, short answer, and multiple choices, though all four types did not appear on all exams.

We used the MBESS program (Dunn *et al.*, 2014; Revelle & Zinbarg, 2009; Kelley, 2007) written for the R platform for statistical computing (Field *et al.*, 2012) to estimate reliability coefficients alpha and omega and their confidence intervals. We used the normal theory bootstrap approach in MBESS, known to be superior to other estimates of reliability, especially for the small sample sizes typical of our classes (Padilla & Divers, 2013a, 2013b). Reliability estimates were each based on 1000 bootstraps.

For 11 of the 12 exams in this study (exams numbered 1-11 in Table 2), we examined three sources of validity evidence: internal structure, face, and content validity (Cizek, 2012; Cizek *et al.*, 2008). Evidence based on internal structure refers to the relationships among exam items and the degree to which test scores of students based on these items support proper interpretation of test scores. The number of questions posed on a test or exam affects reliability, but this, in turn, affects the internal structure validity of exam scores (Rios & Wells, 2014).

We argue that reliability should ideally exceed .70 for the student scores examined in our study (Schmitt, 1996). Many developers of psychological tests employ this standard, though arguably student exam scores need not meet such a stringent standard (Dracup, 1997; Nunnally & Bernstein, 1994).

For face validity, we asked whether or not the course instructors would be willing to use each of the six exam versions as the official final exam in their classes. As well, the instructors rated on a 5-point Likert scale their own opinion of the acceptability of each exam version they used as the official exam for the course (1 = not at all acceptable to 5 = very acceptable).

For content validity (Haynes *et al.*, 1995), we asked instructors two questions using 5-point Likert scales of 1 = not very well to 5 = very well: How well did each exam cover all-important topics covered in the course? How well did the mark allocation on each exam reflect the relative importance of the topics in the course?

Results

Results of student performance in our 22 classes as estimated by reliability coefficients alpha and omega are displayed in Table 2. Both approaches that we used for averaging reliabilities produced virtually identical values and will, therefore, not be discussed further (approaches #1 and #3 in Feldt & Charter, 2006).

Table 2. Reliability estimates for 22 classes in three higher education subjects

					Length		Exam (%)	Reliability	
Class	**Course**	**Prof**	**Exam**	**n**	**t**	**q**	**Mean (SD)**	**α (CI)**	**ω_M (CI)**
F1	Fin I	a	1	60	3.0	37	63.3 (16.9)	.85 (.81, .90)	.87 (.83, .92)
F2	Fin I	a	1	57	3.0	37	67.2 (19.2)	.89 (.86, .93)	.91 (.87, .94)
F3	Fin II	a	2	52	3.0	47	67.7 (14.9)	.85 (.79, .90)	.85 (.79, .91)
F4	Fin II	a	2	55	3.0	47	67.9 (17.2)	.88 (.84, .92)	.89 (.85, .93)
A1	Acc Int I	b	3	37	3.0	36	57.8 (14.0)	.86 (.79, .94)	.89 (.84, .94)
A2	Acc Int II	b	4	22	3.0	33	50.9 (11.4)	.67 (.52, .83)	.73 (.56, .90)
A3	Ac.Topics	b	5	35	2.5	20	61.8 (15.2)	.86 (.81, .92)	.88 (.82, .94)
S1	Stats	c	6	25	3.0	15	64.8 (23.8)	.83 (.77, .90)	.90 (.84, .96)
S2	Stats	c	6	63	3.0	15	71.2 (22.4)	.82 (.79, .86)	.86 (.81, .92)
S3	Stats	c	6	61	3.0	15	67.4 (23.1)	.82 (.79, .86)	.87 (.82, .92)
S4	Stats	d	6	23	3.0	15	77.5 (14.5)	.79 (*, *)	.84 (.74, .94)
S5	Stats	d	7	46	3.0	21	66.7 (19.7)	.74 (.61, .82)	.81 (.73, .90)
S6	Stats	d	8	38	3.0	27	68.8 (15.3)	.71 (.61, .81)	.74 (.61, .86)
S7	Stats	e	9	40	2.5	31	47.8 (15.7)	.84 (.78, .89)	.84 (.76, .91)
S8	Stats	e	9	48	2.5	31	45.5 (19.0)	.88 (.86, .91)	.90 (.88, .93)
S9	Stats	c	10	36	2.0	13	67.6 (19.2)	.81 (.75, .86)	.84 (.77, .92)
S10	Stats	c	10	66	2.0	13	70.9 (20.6)	.80 (.75, .85)	.83 (.77, .89)
S11	Stats	c	10	59	2.0	13	65.1 (21.0)	.79 (.73, .86)	.83 (.77, .90)
S12	Stats	c	11	22	2.0	12	66.5 (26.0)	.87 (.81, .93)	.91 (.84, .97)
S13	Stats	c	11	65	2.0	12	58.2 (23.0)	.80 (.74, .85)	.84 (.77, .90)
S14	Stats	c	11	59	2.0	12	62.8 (22.2)	.79 (.74, .85)	.83 (.76, .89)
S15	Stats	e	12	43	2.0	30	50.0 (19.0)	.83 (.77, .89)	.86 (.80, .92)

Note: Student marks = %; Fin I = Intro Finance I; Fin II = Intro Finance II; Acc Int I = Accounting Intermediate I; Acc Int II = Accounting Intermediate II; Acc Topics = Accounting Special Topics; Prof = professor or instructor who taught the class; *n* = number of students in class; *t* = maximum time allowed for exam completion (hrs); *q* = number of separately marked questions or parts of questions on exam; SD = standard deviation (%); α = coefficient alpha and ω_M = coefficient omega: estimated by MBESS software; and * signifies that the program was unable to compute the confidence interval for α for this class.

Coefficient omega, the most appropriate measure of internal consistency reliability for mixed-format exams, averaged .85 across the 22 classes, with class reliabilities ranging between .73 and .91. The median was marginally higher at .86. Over 90% of the classes tested (20 out of 22) had reliabilities greater than .80. Coefficient alpha, the most commonly used estimate of reliability but an inappropriate one for mixed-format exams, averaged .82 (alphas for these classes ranged between .67 and .88). However, our empirical results confirmed the theoretical prediction that coefficient alpha underestimates actual reliability for mixed-format exams (underestimates ranged from 0 to .07). On average, coefficient alpha underestimated reliability by .035, a rather large and significant difference (sign test, 2 ties excluded, 20/20 classes in predicted direction, $p < .0001$).

Though there appeared to be some differences in the reliability of exam scores across different professors, exams, courses, and fields of study, these differences were relatively small and inconsequential. However, we do not believe our present study permits statistical assessments of these issues. One issue that we did address was whether student scores of shorter examinations would have significantly lower reliabilities. Professor "c" examined students using both 3.0-and 2.0-hr final exams for the same course in introductory business statistics (see Table 2). There was no significant difference in mean reliability between short and long exams given by this professor in this course (independent-groups $t(df = 7) = 1.47$, $p = .09$). We must caution the reader, however, of the unacceptably small sample size of only nine classes used for this test and the lack of independence of some reliability estimates (those based on the same exam albeit for different classes).

Our preceding discussion of the results focused on the point-estimates of α and ω. Using confidence intervals is important when interpreting results for a single class to show the probable range within which the true reliability may fall (see Table 2). For two classes, the range of ω extended below .70. Thus, reliabilities for some classes might not be as high as one might expect if one examines only the point estimate of reliability for the same class.

Instructors judged all exams acceptable on all aspects of face and content validity that we measured (each of the 12 exams was rated either a 4 or a 5 on all 5-point Likert rating scales). Internal structure validity, based on estimates of reliability, was good given that our stringent standard for reliability of at least .80 was met in over 90% of the classes tested in our studies.

Discussion

Score reliabilities of mixed-format exams

Professors in higher education often use exams composed of more than one type of question with variable marks assigned to each question on the exam. The 12 exams described in Table 1 are examples of this type of exam. Many professors mistakenly believe that such mixed-format exams are relatively unreliable and especially poor when compared with the reliability of so-called objective MCQ exams (e.g., Cao, 2008, pp. 1 and 13; DiBattista & Kurazawa, 2011, p. 18). Our study examined the reliability of student exam performance on mixed-format exams in higher education in many classes, in different courses and fields in business, and with different exams, students, and professors.

The most appropriate measure of reliability when one's focus is on decisions affecting students, as it was in our case, is unquestionably internal consistency (Ebel, 1965; Morley, 2014). The most commonly reported measure of this type of reliability is coefficient alpha, but this estimate is widely misused and known to underestimate the true reliability of exams composed of more than one type of question or with questions of unequal value (Dunn *et al.*, 2014; Schmitt, 1996). For mixed-format tests, the congeneric measurement model of reliability has been shown to be most appropriate (Dunn *et al.*, 2014; Feldt & Charter, 2003; Graham, 2006; Qualls, 1995; Revelle & Zinbarg, 2009; Sijtsma, 2009). Several alternative measures of congeneric reliability have been proposed such as the greatest lower bound and coefficient omega (Dunn *et al.*, 2014; Graham, 2006; Sijtsma, 2009). We use coefficient omega to estimate congeneric reliability because of the strength of its mathematical justification and the ability to compute confidence intervals, which permit accurate estimation of the range within which actual reliability for a population is likely to fall (Revelle & Zinbarg, 2009).

In our study, reliability of exam scores was very high with coefficient omega averaging .85 in the 22 classes. Moreover, the reliabilities were remarkably consistent from class to class (ranging from .73 to .91) despite variation in students, professors, exams, fields of study, courses, and classes taught. Scores on the exams in over 90% of the 22 classes tested in our study had reliabilities exceeding .80, our strictest standard or target reliability for exam scores in these quantitative courses. All 22 of the classes tested in our study had score reliabilities exceeding our target standard criterion of .70. Practically speaking, these reliabilities imply that error is relatively small, and decisions based on student performance on this type of exam in the courses tested are relatively well founded.

While the reliabilities for mixed-format exams in our studies are exceptionally high, there is obviously room for improvement in many of the courses in our study. Even a casual inspection of Table 2 suggests that some professors should consider increasing the number of questions posed on their own exams. Generally speaking, the more items posed on a test, the higher the reliability one should expect to find (Crocker & Algina, 2008; Ebel, 1972; Nunnally & Bernstein, 1994).

Comparison of score reliabilities of mixed-format exams with those on other exam types

How do these score reliabilities for mixed-format exams in higher education compare with those obtained by others for single-format exams? In general, they are higher. The reliabilities we have found for mixed-format scores compare favourably with those found by others for MCQ and other types of exam scores in higher education. For example, the lowest reliability for mixed-format exam scores in our studies (.73, see Table 2) exceeds that for all the MCQ exam score reliabilities reported by either Harrison (2014) or Jensen *et al.* (2013) for courses in physics or biology. DiBattista & Kurzawa (2011) also report reliabilities for MCQ exam scores in many courses with 50% of their 16 classes having values lower than .73, the lowest value in our study. These reliabilities, however, undoubtedly overestimate the reliability of exam scores because the authors restricted their investigations to exams having a minimum of at least 25 MCQs. From personal experience we know of many professors who have used final exams with fewer than 25 questions. Harrison's exams, for example, always consisted of fewer than 25 questions, but exams with fewer than 25 questions would likely have had significantly lower score reliabilities than those reported in their study (Nunnally & Bernstein, 1994). As Burton (2005, pp. 66 and 70) asserts, it is a myth that "tests of, say, 60 items generally suffice to sample the facts and ideas taught in a given course." Moreover, "that people have faith in tests with even fewer than 60 items, even as few as 30, is evident from their widespread use."

MCQ tests in academe are known to be generally poor in reliability (e.g., Burton, 2005). Such poor reliability implies that error is relatively high and that decisions based on the results of such MCQ exams could be somewhat compromised. Furthermore, as Burton (2005, p. 66) claims, "what is indisputable is that many [MCQ] tests are indeed badly written and administered", and this undoubtedly lowers the reliability of test scores for MCQ exams.

In contrast, the reliabilities for scores on mixed-format classroom exams in Table 2 are comparable with those reported for costly, professionally developed, standardized clinical and psychological MCQ tests (e.g., Crocker & Algina, 2008; Nunnally & Bernstein, 1994). For example, Williams *et al.* (2004) reports that in the United States, the National Association of State Boards of Geology administers professionally developed exams each year for the licensing of geologists. These examinations consist of two parts, a fundamentals portion and a practice portion. The authors focus only on the fundamentals exams. These exams, four hours in duration, typically consist of 110 MCQs covering topics in all geoscience areas. As Williams *et al.* (2004, p. 377) assert, a reliability standard or target of ".70 or above is generally considered acceptable for licensing exams" such as those for prospective geologists. Moreover, "The exam follows guidelines established in the Standards for Educational and Psychological Testing (1999) published by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education. The test development process is designed to maximize the fairness and quality of the examination as a measure of minimum competency." (p. 376). In their study of the preceding 23 fundamentals examinations administered to prospective geologists, 3 of them had reliabilities lower than .80 while all 23 sets of MCQ exam scores had reliabilities over their standard target of .70. Their results are virtually identical to ours (only 2 out of 22 mixed-format exams had reliabilities lower than .80 and all 22 reliabilities exceeded the same target standard of .70). Yet, classroom exams, unlike professional tests, are normally intended for one-time use (Nunnally & Bernstein, 1994, p. 295), and instructors in academe do not have the time or money to develop tests as professional test developers do. Clearly, reliabilities for mixed-format classroom exams in higher education appear to be at least as good as those for professionally developed MCQ exams.

Conclusions

Based on our review of the literature and our empirical study of the reliability of mixed-format exams in higher education courses, we draw ten conclusions. First, internal consistency reliability is the most appropriate measure of reliability if one's focus is on students (Morley, 2014). Those whose focus is on professors should look to inter-marker estimates of reliability (Dracup, 1997; Morley, 2014). Second, coefficient alpha is the appropriate estimate of internal consistency reliability for exams in which all questions are of one type and all questions are valued equally. However, for mixed-format exams or exams in which questions differ in the marks allotted, coefficient omega is the most appropriate estimate of internal consistency reliability (Dunn *et al.*, 2014). Third, confidence intervals should always be reported for reliability estimates (Fan & Thompson, 2001). Fourth, a standard should always be specified, and a rationale given, for the exam score reliability expected in a course (Fan & Thompson, 2001; Nunnally & Bernstein, 1994). Fifth, exam score reliabilities, such as those reported in the present study, are important for considering the error associated with making decisions about student exam performance (such as pass/fail). Other reliabilities are pertinent if one focus is on decisions concerned with student performance in an entire course or in an entire program of courses. Sixth, the many different methods that exist for averaging reliabilities are relatively unimportant because the means are virtually identical (Feldt & Charter, 2006). Seventh, student exam scores on actual mixed-format exams in higher education are, contrary to popular opinion, highly reliable (with, for example, over 90%

of the reliabilities for the 22 classes in our study exceeding .80). Eighth, given the many advantages of mixed-format exams articulated in our introduction as well as the exceptionally high internal consistency reliabilities found in our empirical study, professors in higher education might wish to give serious consideration to the use of this type of exam in their own courses. Ninth, our review of the literature also suggests that professors lacking the psychometric expertise and knowledge of how to construct fair, effective, and reliable MCQ exams would be well advised to avoid the use of such exams (Burton, 2005). The reader should not misconstrue our conclusions to imply (erroneously) that we are condemning the use of MCQ exams (or, for that matter, essay-only or problem-solving-only exams). To the contrary, we believe each type of exam has a role to play in testing students in higher education. We do argue, however, that mixed-format exams have been unjustifiably criticized as well as grossly neglected in the literature on examinations and have not received proper consideration by professors in higher education for use in testing students. Tenth, more researchers need to turn their attention to investigating the strengths and weaknesses of using mixed-format classroom exams in academe. Given the surprisingly positive results of the present empirical study together with the complete absence of previous research published in the literature on the use of mixed-format exams in higher education (or in any other area for that matter) suggests that much remains to be done.

Future work

The present study, however, raises several new questions: exam length, validity, and comparability. First, the number of questions in an exam affects the reliability and, therefore, possibly the validity of student exam scores (Messick, 1989). The question of whether reliability can be increased by lengthening a mixed-format exam, perhaps by increasing the number of questions posed on the exam, is a particularly important one. We did not investigate this issue here. Nevertheless, many researchers have reported higher reliabilities for longer single-format tests (Burton, 2006; Ebel, 1972; Fitzpatrick & Yen, 2001; Murphy, 1978). As well, theoretical considerations suggest this is so (e.g., Crocker & Algina, 2008; Nunnally & Bernstein, 1994). “Spearman's (1910) assertion that lengthening a test will improve its reliability and, indirectly, its validity had an intuitive appeal and seems to have guided test construction practice to this day” (Burisch, 1997). In the absence of empirical evidence, however, the applicability of the Spearman-Brown prophecy formula to mixed-format exams is questionable given the unrealistic assumptions required for this equation to hold. Burisch (1997) also cautioned that increasing the length of some tests too much might compromise the validity of a test. Lee *et al.* (2015) report on a preliminary investigation of the question of exam length for mixed-format exams.

A second important question is validity. Validity is the degree to which exams measure what they are purported to measure. Internal consistency reliability does not ensure validity (Zimmerman *et al.*, 1993). It does, however, set an upper bound on the possible validity associated with the exam. Consequently, the high reliabilities for the mixed-format exam scores in the 22 classes in our study suggest that validity based on the evidence for internal structure has a high upper limit possible (Rios & Wells, 2014). Making distinctions among different forms of validity has been discouraged in recent years (Cizek, 2012; Cizek *et al.*, 2008).

Nevertheless, we argue that for classroom examinations in higher education, the focus should be primarily on content validity and to a lesser extent on validity evidence based on face and internal structure. Content validity assesses how well the questions on an exam sample the content covered in a course and that the allocation of marks on the exam reflects the importance of, and time spent on, question topics during class. The usual approach for establishing evidence for this type of validity is by effective planning and design (Cizek *et al.*, 2008). All professors in the study used this approach. As well, professors of a given course judged their own exam scores to be content and face valid. Both forms of validity depend upon reliability without which validity is irrelevant. However, high exam score reliability does not guarantee that the exam will be valid. As well, in our present studies, we asked only the course instructors to assess face and content validity for their own exams. Haynes *et al.* (1995), however, strongly recommends that multiple professors (at least three) should ideally make such validity judgments, and not just a single professor for each exam as in our study.

A third question raised by our study is whether the mixed-format exams in these three disciplines really comparable? This is an important issue. In Table 1, the descriptions of the types of questions posed on the 12 mixed-format exams in our study illustrate the diversity that occurs between different versions of this type of exam. Several arguments can be advanced for believing that at least some of the exams are comparable. All courses examined in our study are, for example, in applied disciplines (e.g., accounting). All exams included both strong quantitative and strong non-quantitative or narrative components. Each mixed-format exam also included many problem-solving and narrative short-answer questions. Nevertheless, another response to this question is that they are certainly not. Questions on finance exams bear little resemblance to those on statistics exams. Even within a discipline, exams on introductory courses can differ radically from those on more advanced courses. However, readers will certainly differ in what they believe constitutes exam comparability. This is why the reliabilities are provided for each exam in each of the classes, courses, and disciplines studied (see Table 2). Finally, one must consider that, despite these manifold differences, reliabilities for these widely divergent exams were uniformly high in our study (more that 90% had reliabilities exceeding .80).

Limitations of present study

Several limitations must be stressed. First, in this paper we focussed exclusively on investigating internal consistency reliability to the exclusion of other forms such as inter-marker reliability, which explore different sources of error (Crocker & Algina, 2008). Similarly, the issues of moderation, a method for improving marker consistency in which several markers meet to iron out differences, and calibration, in which markers learn to mark more consistently by working with other markers, are both concerned with inter-marker reliability (Sadler, 2013), and therefore, while important issues in their own right, were not the focus here. Second, our interpretation of the present results must be tempered somewhat by the relatively small number of exams, instructors, classes, courses, and subject fields tested in the present study. Third, unlike single-format exams, mixed-format exams can vary considerably with, for example, one exam containing essays and MCQs while another may consist of only short answer and problem solving questions (see Table 1). In forthcoming studies, our objective is to cover more subject areas, courses, classes and students, exams, and professors. Additionally, we hope to explore whether there are systematic, predictable differences among different versions of mixed-format exams.

Concluding remarks

Both researchers and professors of courses in higher education should, in our opinion, give more attention to assessing the strengths and weaknesses of mixed-format classroom exams. Our study and review of the reliability literature suggests this type of examination, when used in higher education classrooms, has reliabilities that are far superior to those of other types of classroom exams (such as essay or MCQ exams) and at least as good as those reported for professionally developed standardized licensing exams or clinical tests.

References

Ackerman, P., Kanfer, R., Shapiro, S. W., & Newton, S. (2010). Cognitive fatigue during testing: An examination of trait, time-on-task, and strategy influences. *Human Performance*, *23*, 381-402.

Alexander, R. (1990). A note on averaging correlations. *Bulletin of the Psychonomic Society*, *28*, 335-336.

Biggs, J. (2003). *Teaching for quality learning at university*. 2nd edition. Buckingham, UK: Society for Research into Higher Education and Open University Press.

Brennan, R. L. (2001). An essay on the history and future of reliability from the perspective of replications. *Journal of Educational Measurement*, *38*, 295-317.

Burisch, M. (1997). Test length and validity. *European Journal of Personality*, *11*, 303-315.

Burton, R. F. (2005). Multiple-choice and true/false tests: myths and misapprehensions. *Assessment and Evaluation in Higher Education*, *30*(1), 65-72.

Burton, R. F. (2006). Sampling knowledge and understanding: how long should a test be? *Assessment and Evaluation in Higher Education*, *31*(5), 569-582.

Cao, Y. (2008). *Mixed-format test equating: Effects of test dimensionality and common-item sets.* Doctoral dissertation. Department of Measurement, Statistics and Evaluation, University of Maryland.

Cizek, G. J. (2012). Defining and distinguishing validity: interpretations of score meaning and justifications of test use. *Psychological Methods*, *17*, 31-43.

Cizek, G. J., Rosenberg, S. & Koons, H. (2008). Sources of validity evidence for educational and psychological tests. *Educational and Psychological Measurement, 68,* 397-412.

Considine, J., Botti, M. & Thomas, S. (2005). Design, format, validity and reliability of multiple choice questions for nursing research and education. *Collegian*, *12*(1), 19-24.

Corey, D., Dunlap, W. & Burke, M. (1998). Averaging correlations: Expected values and bias in combining Pearson *r*s and Fisher's *z* transformations. *Journal of General Psychology*, *125*, 245-261.

Cox, R. (1967). Examinations and higher education: A survey of the literature. *Higher Education Quarterly*, *21*, 292-340.

Crocker, L. & Algina, J. (2008). *Introduction to classical and modern test theory*. Fort Worth: Harcourt, Brace and Jovanovich.

Cumming, G. & Finch, S. (2001). A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. *Educational and Psychological Measurement, 61,* 532-574.

DiBattista, D. & Kurzawa, L. (2011). Examination of the quality of multiple-choice items on classroom tests. *The Canadian Journal for the Scholarship of Teaching and Learning*, *2*(2), article 4, 1-23.

Dracup, C. (1997). The reliability of marking on a psychology degree. *British Journal of Psychology, 88,* 691-708.

Dunlap, W., Silver, N. & Bittner, A. (1986). Estimating reliability with small samples: Increased precision with averaged correlations. *Human Factors*, *28*, 685-690.

Dunn, T., Baguley, T., & Brunsden, V. (2014). From alpha to omega: a practical solution to the pervasive problem of internal consistency estimation. *British Journal of Psychology, 105*, 399-412.

Ebel, R. L. (1965). *Measuring educational achievement*. Englewood Cliffs, NJ: Prentice-Hall.

Ebel, R. L. (1972). Why is a longer test usually a more reliable test. *Educational and Psychological Measurement, 32,* 249-253.

Fan, X. & Thompson, B. (2001). Confidence intervals about score reliability coefficients, please: An EPM guidelines editorial. *Educational and Psychological Measurement, 61,* 517-531.

Feldt, L. S. (2002). Estimating internal consistency reliability of tests composed of testlets varying in length. *Applied Measurement in Education*, *15*, 33-48.

Feldt, L. S. & Brennan, R. L. (1989). Reliability. In Linn, R. L. (Ed.), *Educational measurement*. 3rd ed. American Council on Education/Macmillan, New York, pp. 105-146.

Feldt, L. S. & Charter, R. A. (2003). Estimating the reliability of a test split into two parts of equal or unequal length. *Psychological Methods, 8*(1), 102.

Feldt, L. S. & Charter, R. A. (2006). Averaging internal consistency reliability coefficients. *Educational and Psychological Measurement, 66*(2), 215-227.

Field, A., Miles, J. & Field, J. (2012). *Discovering statistics using R*. London: Sage Publications, Ltd.

Fitzpatrick, A. R. & Yen, W. M. (2001). The effects of test length and sample size on the reliability and equating of tests composed of constructed-response items. *Applied Measurement in Education*, *14*(1), 31–57.

Frisbie, D. A. (1988). Reliability of scores from teacher-made tests. *Educational Measurement: Issues and Practice, 7*, 25-35.

Graham, J. M. (2006). Congeneric and (essentially) tau-equivalent estimates of score reliability what they are and how to use them. *Educational and Psychological Measurement, 66*(6), 930-944.

Harrison, D. (2014). The uncertainty of grades in physics courses is surprisingly large. *Physics in Canada*, *70*(2), 75.

Haynes, S. N., Richard, D. C. S. & Kubany, E. S. (1995). *Psychological Assessment*, *7*(3), 238-247.

Henchy, A. M. (2013). *Review and evaluation of reliability generalization research*. (Doctoral dissertation, Educational, School, and Counseling Psychology, University of Kentucky, 2013).

Henson, R. (2001). Understanding internal consistency reliability estimates: A conceptual primer on coefficient alpha. *Measurement and Evaluation in Counseling and Development, 34,* 177-189.

Hill, B. J. (1978). Examination paper length: How many questions? *British Journal of Educational Psychology, 48*, 186-195.

Hogan, T. P., Benjamin, A. & Brezinski, K. L. (2000). Reliability methods: A note on the frequency of use of various types. *Educational and Psychological Measurement*, *60*(4), 523-531.

Hunter, J. & Schmidt, F. (1990). *Methods of meta-analysis: Correcting error and bias in research findings*. Newbury Park, CA: Sage.

Jensen, J., Berry, D. & Kummer, T. (2013). Investigating the effects of exam length on performance and cognitive fatigue. *PLoS ONE, 8(8),* 1-9, e70270.

Jones, L. V. & Thissen, D. (2007). A history and overview of psychometrics. *Handbook of Statistics*, *26*, 1-27.

Kelley, K. (2007). Methods for the behavioral, educational, and social sciences: An R package. *Behavior Research Methods, 39(4),* 979-984.

Krippendorff, K. (2004). Reliability in content analysis: Some common misconceptions and recommendations. *Communications Research*, *30*(3), 411-433.

Lee, E., Bygrave, C., Mahar, J., Garg, N. & Cottreau, S. (2014). Can exams be shortened? Using a new empirical approach to test in finance courses. *Proceedings of the International Conference on Higher Education and Management (ICHEM 2014)*, London, UK, January 2014.

Lee, E., Garg, N., Bygrave, C., Mahar, J. & Mishra, V. (2015). Can university exams be shortened? An alternative to problematic traditional methodological approaches. Published in the *Proceedings of the 14th European Conference on Research Methodology for Business and Management Studies*, University of Malta (pp. 243-251).

Lord, F. M. & Novick, M. R. (1968). *Statistical theories of mental test scores*. Reading, MA: Addison-Wesley.

Meadows, M., & Billington, L. (2005). A review of the literature on reliability. National Assessment Agency.

Messick, S. (1989). Validity. In R. Linn (Ed.), *Educational measurement*. New York: American Council on Education and Macmillan, 13-103.

Miller, M. (1995). Coefficient alpha: A basic introduction from the perspectives of classical test theory and structural equation modelling. *Structural Equation Modeling, 2,* 255-273.

Morley, D. (2014). Assessing the reliability of student evaluations of teaching: Choosing the right coefficient. *Assessment & Evaluation in Higher Education*, *39*(2), 127-139.

Munro, N., Denny, M. L., Rughani, A. Foulkes, J., Wilson, A. & Tate, P. (2005). Ensuring reliability in UK written tests of general practice: the MRCGP examination 1998-2003. *Medical Teacher*, *27*, 37-45.

Murphy, R. J. L. (1978). Reliability of marking in eight GCE examinations. *British Journal of Educational Psychology*, *48*, 196-200.

Newstead, S. (2002). Examining the examiners: Why are we so bad at assessing students? *Psychology Learning and Teaching*, *2*(2), 70-75.

Nunnally, J. & Bernstein, I. (1994). *Psychometric theory*. 3rd edition, Toronto: McGraw-Hill.

Padilla, M. A., Divers, J. & Newton, M. (2012). Coefficient alpha bootstrap confidence interval under nonnormality. *Applied Psychological Measurement, 36*(5), 331-348.

Padilla, M. A. & Divers, J. (2013a). Coefficient omega bootstrap confidence intervals: Nonnormal distributions. *Educational &Psychological Measurement, 73*, 956-972.

Padilla, M. A. & Divers, J. (2013b). Bootstrap interval estimation of reliability via coefficient omega. *Journal of Modern Applied Statistical Methods*, *12*, 78-89.

Peters, G.-J. Y. (2014). The alpha and the omega of scale reliability and validity. *The European Health Psychologist*, *16*, 56-69.

Qualls, A. L. (1995). Estimating the reliability of a test containing multiple item formats. *Applied Measurement in Education, 8,* 111-120.

Revelle, W. & Zinbarg, R. E. (2009). Coefficients alpha, beta, omega, and the glb: Comments on Sijtsma. *Psychometrika, 74*(1), 145-154.

Rios, J. & Wells, C. (2014). Validity evidence based on internal structure. *Psicothema*, *26*, 108-116.

Sadler, R. (2013). Assuring academic achievement standards: from moderation to calibration. *Assessment in Education: Principles, Policy and Practice*, *20*(1), 5-19.

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment*, *8*, 350-353.

Sijtsma, K. (2009). On the use, misuse, and the very limited usefulness of Cronbach's alpha. *Psychometrika*, *74*, 605-632.

Silver, N. & Dunlap, W. (1987). Averaging correlation coefficients: Should Fisher's transformation be used? *Journal of Applied Psychology*, *72*, 146-148.

Smithson, M. (2001). Correct confidence intervals for various regression effects and parameters: The importance of noncentral distributions in computing intervals. *Educational and Psychological Measurement, 612,* 837-847.

Tavakol, M. & Dennick, R. (2011). Post-examination analysis of objective tests. *Medical Teacher*, *33*, 447-458.

Thompson, B. (1994). Guidelines for authors reporting score reliability estimates. *Educational and Psychological Measurement, 54,* 837-847.

Thompson, B. (1999). If statistical significance tests are broken/misused, what practices should supplement or replace them? *Theory and Psychology, 9,* 165-181.

Thompson, B. (2003). Understanding reliability and coefficient alpha, really. In B. Thompson (Ed.), *Score reliability* (pp. 3-23). London, UK: Sage Publications.

Thompson, B. & Vacha-Hasse, T. (2000). Psychometrics is datametrics: The test is not reliable. *Educational and Psychological Measurement, 60,* 174-195.

Whittington, D. (1998). How well do researchers report their measures? An evaluation of measurement in published educational research. *Educational and Psychological Measurement, 58,* 21-37.

Wilkinson, L. & the APA Task Force on Statistical Inference (1999). Statistical methods in psychology journals. *American Psychologist*, *54*, 594-604.

Williams, J. W., Warner, J. L. & Warner, S. P. (2004). Subject-area knowledge measured by scores on the National Association of State Boards of Geology (ASBOG) fundamentals examination and the implications for academic preparation. *Journal of Geosciences Education*, *52*(4), 374-378.

Wilmut, J., Wood, R. & Murphy, R. (1996). *A review of research into the reliability of examinations*. A discussion paper prepared for the School Curriculum and Assessment Authority.

Zimmerman, D. W., Zumbo, B. D. & Lalonde, C. (1993). Coefficient alpha as an estimate of test reliability under violation of two assumptions. *Educational and Psychological Measurement, 53,* 33-49.

Chapter 8

Development of a Classification Scheme for Errors Observed in the Process of Computer Programming Education

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Abstract: Every semester, we observe more or less the same principal difficulties among our students who are striving to learn the intricacies of software development. Basically, throughout their learning process they run into the same kind of errors as previous student generations. Based on this fact, we suspect that there is a set of underlying problems which are causing these errors. Our goal is to identify and tackle these basic problems, in order to deal with errors effectively in our teaching and coaching activities, rather than merely treating observable symptoms. To achieve this, we develop a comprehensive and topic-independent error classification scheme and employ this to classify errors found in literature and in our own courses. This classification scheme is mainly based on the cognitive dimensions of the revised Bloom's taxonomy for educational objectives. Each error is based on a deficiency in certain competencies. Therefore, it is possible to develop a set of interventions for each error class, which focuses on the specific deficits that are the main cause for all the errors of this class.

Keywords: Computer Science Education; Student Assessment

Introduction

Many years of experience in teaching software development and software engineering in higher education have shown that over and over again, a significant part of each new generation of students runs into more or less the same principal difficulties and produces the same kind of errors throughout their learning process. Informal discussions with colleagues (both national and international), as well as literature research, implies that many of these difficulties and errors occur universally and thus seem to be of a more general nature, rather than being caused by our own individual teaching styles.

For example, the notion of 'if-loop' (rather than 'if-then-else' or 'choice' being the correct technical term) is still widely spread, although all the lecturers whom we have personally asked so far swear that they have never ever said 'if-loop' when students were present.

As the work of a significant number of students shows the same errors, we suspect that there is some set of underlying problems that is responsible for causing these errors. To deal with these errors in an effective way, we therefore have to identify these basic problems, rather than merely curing the symptoms that have been observed in individual cases.

Goals

Students' difficulties and errors observed in the process of computer science education and, more specifically, software development education, are manifold. In fact, there are so many of them that it is almost impossible to deal with each error individually.

Instead, we attempt to categorise the observed difficulties and errors and cluster them into classes. As key criterion for this classification, we use the underlying problem that causes the observed difficulties and errors. More precisely, we focus on which basic *competency* is insufficient or lacking completely, but would avoid the problem if it were sufficiently developed.

To validate our classification scheme, we categorise a number of typical errors, both from literature and those identified in class work of our own students.

Thus, firstly we aim to understand the underlying causes of the observed errors. Secondly, we boil them down to a manageable set of crucial competencies that must be sufficiently developed in our students, so that they are able to effectively acquire the computer science related expertise required for the academic degree they aspire to. On this basis, we are developing a set of interventions which systematically address those base competencies that are identified as being crucial, but missing in our students.

State of the Art

Error classification schemes have already been investigated to a certain extent. To gain a comprehensive overview of typical faults and ’things that are done wrong’, we extended our literature review on *errors* to the general area of STEM (science, technology, engineering, and mathematics). However, as classification schemes tend to be more domain-specific, we focused our review of existing *classifications* in this section on the domain of computer science.

A list of common programming errors named in literature can be found in the section on validation below. Furthermore, the context of the studies, the errors are listed, is described.

Errors and Misconceptions

The most comprehensive term for ‘things that are done wrong’ is the concept of *error*. An error is “the state or condition of being wrong in conduct or judgment” (Dictionary). For example, an error in an exam is everything that is incorrect or a missing answer where an answer would be required. A study that extensively uses this term is published by Hristova *et al.* (2003).

Another common term is *misconception*. It is often used in scientific papers, but usually not defined explicitly. Misconceptions and their influence on teaching are discussed in many disciplines, like physics, chemistry (Barke, 2006), biology (Dreesmann, Graf, & Witte, 2012) or computer science (Pea, 1986).

For the notion of misconception, many synonymous terms are used in literature, such as *alternative conceptions* (Barke, 2006), *preconceptions* (Barke, 2006)*, naive beliefs* or *bugs* (Pea, 1986). These terms are often preferred, because they sound more positive. However, Bahar (2003) states that the term *misconception* is widely used in research and that it is well-known to the public. Furthermore, the term indicates that the concept in a student's mind differs from the scientific concepts. Thus, we prefer the notion of misconception over the alternatives. Hence, this expression is used throughout this work.

If students' existing ideas are a misconception rather than correct knowledge, problems will occur when new content in this area is provided, e.g. when the misconception runs contrary to the true scientific concept. As a consequence, as all new information is interpreted based on existing knowledge, undetected misconceptions will seriously inhibit the learning process.

In our opinion, Dreesmann, Graf, & Witte (2012) uses the most complete definition, naming all relevant characteristics of a misconception. Accordingly, in this paper we use the following definition translated into English from (Dreesmann, Graf, & Witte, 2012) which is originally in German: *Misconception is a logical and coherent concept. Thus, it fits into personal experience and knowledge. Nevertheless, it is wrong or contrary to scientific concepts.*

Known Error Classifications

Most of the errors described in literature are either not classified at all (such as Humbert (2006a, 2006b) and Rabel (2011)), or classified by a schema based on the content domain, in whose teaching the error occurred.

For example, Sorva (2008) uses three classes of errors: understanding of variables, understanding of object variables, and understanding of the relationship between primitive and object variables. These error classes are specific for the understanding of data storage topics, but would not work with algorithms, for example.

The paper "Exploring Programming Misconceptions" (Sirkiä & Sorva, 2012) investigates different types of errors, classified as: miscellaneous basic concepts, functions, or object-oriented programming. Thus, they are following the topics of introductory courses on software development.

As a consequence, errors in more advanced topics, like threading or generics, are difficult to classify, as they usually involve a variety of problems from different fundamental topics.

In contrast, Hristova, Misra, Rutter, & Mercuri (2003) and Pea (1986) introduce more general classifications. Pea (1986) derives three classes of errors from one "superbug". The superbug describes that many students implicitly assume that a computer can think, or interpret, or has a mind. From this initial superbug, students derive a variety of erroneous notions; for example, that different lines of code can be active at the same time; or that a program can act in foresight; or that computers can do something that has not been specified in the program.

In addition, Hristova *et al.* (2003) classify errors according to a schema which is well-established in computer science, i.e. into syntactic, semantic and logic errors.

Syntax errors are the ones based on misspelling, punctuation and word order in a program. *Semantic errors* occur on a higher intellectual level. They deal with the meaning of the code and arise from mistaken ideas of how a programming language interprets certain instructions. Finally, *logic errors* are the most general type of error, as they result from the programmer's misguided thinking, rather than from language characteristics.

Detection and Clustering of Errors

In order to use any classification scheme, it is necessary to be aware of the errors that have to be classified. Several methods to identify errors are known from literature:

Sirkiä (2012) analyses solutions that students submitted to a system for Visual Program Simulation (VPS). In contrast to this, in the study of Sorva (2008), students are interviewed.

To identify and cluster errors, we use the following techniques:

- Similar to Sirkiä & Sorva (2012), we analyse solutions that students turned in as assignments or in exams. To this end, we go through the pile of solutions twice. In the first iteration, we scan through all the solutions, to identify and take notes on the observed errors. Then, we organise the observed errors into clusters, leading to a collection of some three to eight main clusters. In the second iteration, we resurvey all the solutions and assign each erroneous solution to an error cluster. Having accomplished this, we are able to count the number of hits for each cluster. The higher the number of solutions in a cluster, the more important it is to identify the cause of the error and to find an adequate remedy. This process is depicted in Figure 1.
- We observe our students throughout their lab sessions and try to analyse and categorise their errors on the fly. In this setting, we are able to immediately ask them questions regarding their solutions. Thus, we can retrieve valuable information on underlying problems that led to their errors.
- In our previous teaching experience, we have collected errors that are made by a significant number of programming novices. If we are aware of an error that frequently occurs in a specific context, we ask questions or design assignments in a way that is likely to provoke this error, thereby making the underlying problems visible. Thus, we help students to become aware of their error, to reflect on their own thinking and, finally, to reach a correct solution on their own.

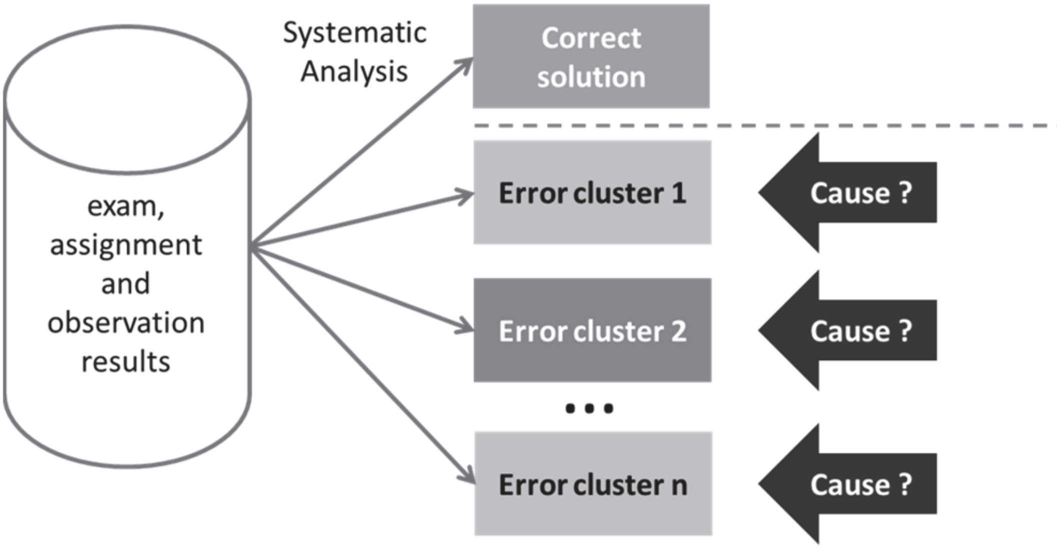

Figure 1. Error identification process

As an example, we look into one of the initial exercises that our first year students have to solve in their introductory course on software development. Here, students are required to implement a Java class *Sheep*, to represent and draw a sheep composed from several ellipses, which are used as basic shapes. We provide a class for drawing ellipses, hints on coordinates of the sheep's parts, as well as a screenshot showing a prototype of our sheep. In the exercise, the sheep is required to change its colour and its position.

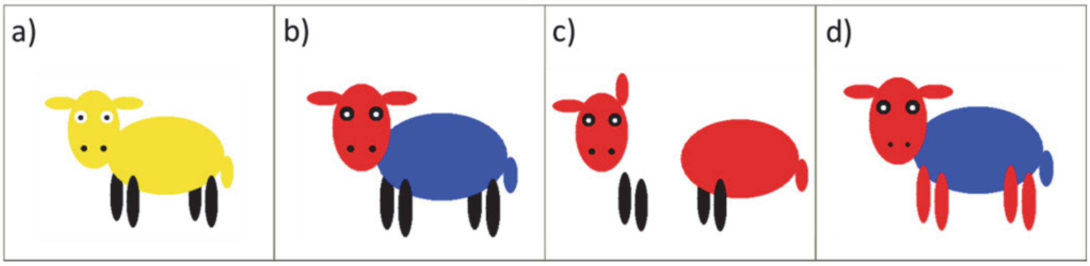

Figure 2. Different examples of sheep programmed and turned in by our students. We see one correct variant (a) and three kinds of errors: colour hard-coded (b), insufficient passing of parameters for coordinates (c), and wrong drawing order (d)

Figure 2. (a) depicts a correct solution, where all the woolly parts of the sheep are of the same colour and the sheep is topologically correct. Sheep (b) is multi-coloured. When the sheep is moved, sheep (c) has its torso severed from the rest of its body parts. Sheep (d) is multi-coloured like sheep (b), and has all of its four legs in front of its body, rather than two legs on the off-side and two on the side facing the front. In addition, several students did not have any clue what to do, and were unable to create anything at all. Each of these errors represents one error cluster.

For all the identified and clustered errors, in a next step we try to conjecture the reason why students solved the problem exactly in the way they did. Understanding the students' thought process is crucial for finding the cause of this kind of error, which, in turn, is a prerequisite for successfully dealing with the principal error, rather than just correcting mere symptoms.

To achieve this, we look into the technical realisation of the different sheep error classes. Here, we discover that the error in sheep (b) is caused by hard-coding colour values by copy-and-paste, rather than parameterising the colour information. Sheep (c) was butchered by not passing parameters for coordinates from the body to the parts, whereas the creators of sheep (d) first drew the sheep's body and all the sheep's legs afterwards, being unaware that the sequential processing order of the different statements influences the final result.

Obviously, the visible error symptoms are highly specific to the exercise in question. However, the underlying problems as well as their *causes* are of a more general nature. Therefore, as a next step we develop a scheme to classify errors according to their causes.

Classification Scheme

We deem the error classifications described in literature so far to be insufficient, as they are highly specialised and thus do not provide a single general classification approach that is suitable for a large variety of errors.

When searching for a more comprehensive and topic-independent classification scheme, our central idea is to relate error causes to the competency levels and categories of cognitive processes that were defined by the revised Bloom's taxonomy (Anderson, et al., 2001). In our teaching experience, this taxonomy has proven to be a suitable basis for describing teaching goals. Usually, the revised Bloom’s taxonomy is used to describe competencies on different skill levels. Analogously, it is possible to categorise the identified deficiencies according to the corresponding Bloom levels.

More precisely, the revised Bloom's taxonomy focuses on the cognitive domain. It is structured into six increasingly complex levels called *cognitive process dimensions* (see Table 1.), which classify the learners' thinking behaviour. Each of these dimensions has several sub-dimensions, to allow for a more detailed clarification of the levels (Anderson, et al., 2001). Furthermore, Anderson *et al.* (2001) distinguish four general types of knowledge, i.e. *factual*, *conceptual*, *procedural* and *metacognitive knowledge*.

Table 1. Cognitive process dimensions according to (Anderson, et al., 2001), and their definitions

Level	Categories and cognitive processes	Definition
1	REMEMBER	Retrieve relevant information from long-term memory.
2	UNDERSTAND	Construct meaning from instructional messages. Build connections between new information and prior knowledge.
3	APPLY	Locate and use procedures to perform exercises (familiar and routine approaches) and solve problems (procedure initially not known).
4	ANALYSE	Break material down to its components and identify how the parts are related and what is the overall structure.
5	EVALUATE	Make judgments based on criteria (e.g. quality, effectiveness, efficiency and consistency) and standards.
6	CREATE	Put elements together to form a new product. Mentally reorganise parts into a pattern not clearly presented before.

In our error classification scheme, we organise errors in a way that is similar to Bloom's taxonomy, in that it specifies what kind of competency is lacking, thus causing the observed error (see Table 2.). In addition, we name and characterise each error class and relate it to its corresponding Bloom level, i.e. the competence level that is deficient if this error occurs.

Lack of accuracy (sloppiness) is independent of all the cognitive processes described in the revised Bloom's taxonomy. Therefore, we introduce another category that is below all of those categories defined by (Anderson, et al., 2001). Inspired by Donald E. Knuth (1989), we name it *MENTAL TYPO*, indicating a lack of concentration, accuracy or, as Knuth says, 'less brainpower left for small details'. An example would be to leave out the parentheses after a method call or to forget a semicolon.

KNOWLEDGE GAP is the second class of error. It correlates to Bloom's REMEMBER level. Typical deficits would be not knowing one's type of learner, too little diligence or not learning definitions by heart. In a context of informatics education, this could occur if students do not know the definition of the terms class and object. Furthermore, it could be that students think Java String is a primitive data type, as they REMEMBER a misconstrued and thus incorrect definition.

The third class is called *MISCONCEPTION*, which is partly what has been defined in section 'State of the Art'. The new definition includes wrong and missing connections.

Thus, if students interpret new information in a wrong way, and form their understanding on this basis, this results in a misconception. Furthermore, not understanding an issue or a topic is also a misconception in this schema. Hence, students with an error in this class were not able to connect new information correctly with previous knowledge, or they built wrong connections. One common example is that students are often unable to distinguish between identity and equality, which is an important concept in many programming languages.

WRONG CHOICE is the term selected for the fourth class. The term indicates that the student has a faulty mapping of a problem to the solution process, or vice versa. This error can have two reasons: a wrong problem classification or the selection of an inappropriate solution mechanism. Using an `enum` instead of `inheritance` is an example of this error class.

Error class five describes the inability to identify and to distinguish components and their internal interaction, in a given setting. Thus, we call this error class *STRUCTURAL BLINDNESS*. An instance of this error class is that students are unable to understand or debug external code. Another example is that students have difficulties in analysing a task description. The underlying deficit is the inability to structure unknown content, a lack of identifying structure and the inability to work systematically and methodically.

A *QUALITY GAP* occurs if a deficit in pragmatism exists. Another error that is rather specific for the area of computer science is a transfer problem. Students are not able to transfer quality standards concerning software to their personal or unknown code. This could appear in code snippets like `FIVE = 5;` for a definition of a constant value. More generally, any student who writes code that is logically correct, but does not meet the quality standards, has a quality gap – provided we are sure that they had already been taught about quality standards (otherwise this could also very well be a knowledge gap).

The final error class is *LACK OF INNOVATION*, corresponding with Bloom's level CREATE. For example, students are unable to create an appropriate algorithm to solve a specific task. Furthermore, if a student copies another student's solution or does not hand in anything at all, this is included in this error class as well. Deficits behind this error might be insufficient creativity or the inability to synthesise individual pieces of information.

Table 2. Classification scheme for errors, including a description of the error, the underlying deficits as well as the competencies that are lacking in each case

Error Class		Description	Deficits in Base Competencies	Lack of
6	LACK OF INNOVATION	Inability to imagine a new product or synthesise a new solution from known information and methods.	Ability to synthesise a lot of information	Being creative and innovative
5	QUALITY GAP	Inability to evaluate software (either self-created or ready-made) against general quality standards.	Pragmatism, transfer general criteria to specific example	Thinking concretely and critically
4	STRUCTURAL BLINDNESS	Inability to distinguish components and their internal interaction, in a given setting.	Ability to structure unknown/ external data according to a systematic and methodical approach	Being able to structure
3	WRONG CHOICE	Wrong problem classification and selection of solution process.	Ability to find a correct solution process for a given problem, with respect to the context	Decision-making, evaluating;thinking holistically and analytically
2	MISCONCEPTION	Faulty concept in mind that fits into previous personal experiences, or not understanding a concept at all.	Correct connection between new information and previous knowledge	Thinking holistically
1	KNOWLEDGE GAP	Not knowing definitions or terms.	Diligence, knowledge about oneself (e.g. type of learner)	Being able to reflect
0	MENTAL TYPO	Sloppy work.	Concentration, brainpower to get the small details right, nervousness	Being accurate, focused, and efficient

Process of Classifying Errors Using the Error Classification Scheme

Errors can be detected in many situations, like exams, laboratory sessions or any other classwork. In the following, we describe the process of how new errors can be classified using the error classification scheme. To support this classification process, we suggest a set of core questions that may guide and support lecturers while classifying errors.

We assume that the error classes zero to three do not necessarily build on each other. Whereas, higher levels are consecutive, starting with level three. This means, if students do not know a definition, they will not necessarily make an error on level two and higher as well. On the other hand, if they do not know how to choose the correct method to solve a problem, they will not be able to combine methods in order to come up with an innovative product. Nevertheless, we always start with asking whether the error is a MENTAL TYPO or not. Afterwards, we sequentially check the other error classes.

In order to guide lecturers while assigning new errors in the error classification scheme, we offer a set of central questions in Table 3. An error belongs to a class, if at least one question aligned to this class can be answered with ‘yes’. It is important to always start with questions on level zero. This is why Table 3 is organised in ascending order.

During this classification process, we have the following assumptions:

- The lecturer defined the right learning objectives on the correct Bloom level. If, for example, he/she requires the students to be able to choose the correct approach from a set of potentially possible ones, the lecturer should have a learning objective, which represents this.
- The lecturer practiced this kind of tasks during lab sessions, in-class work or in homework assignments.
- The lecturer asked exam questions on the Bloom level the students were taught and which they practiced.

All this corresponds to the approach of ‘constructive alignment’ according to Biggs (1996) which we see as prerequisite for using the scheme.

On higher levels it is more and more difficult to discover what students thought during their problem solving process, i.e. how and why they came up with their specific solution. In this case, the most reliable approach is to interview those students who made a specific error. They should explain their thought process, as described in (Sorva, 2008). Based on these insights, it is usually rather easy to identify the lacking competence, which helps to position the error within the error classification scheme, or to answer the core questions. If interviews are not possible, e.g. because they are too time-consuming, lecturers can rely on their experience from former semesters and literature.

In the following subsection, we describe errors we found in literature and our classes as well as how we classified them using the error classification scheme.

Table 3: Core questions for assigning an error to the error classification scheme

Error Class		Core Questions
0	**MENTAL TYPO**	- Is it a sloppy mistake, like forgetting a semicolon? - Is it reasonable to assume that the student knew the answer but just did not think about it?
1	**KNOWLEDGE GAP**	- Would pure knowledge of the topic be sufficient to answer the question?
2	**MISCONCEPTION**	- Is there a similar but contrary understanding in daily life, and did the student follow this concept?
3	**WRONG CHOICE**	- Are there several conceptually similar or related approaches, and did the student choose one of these?
4	**STRUCTURAL BLINDNESS**	- Did students treat things of the same category differently or things of different categories identically?
5	**QUALITY GAP**	- Is the functional requirement met? - Are the quality standards violated?
6	**LACK OF INNOVATION**	- Did the student try to solve the problem with an adapted solution from the lecture or practical session? - Did the student choose the wrong approaches to synthesis? - Did the student choose the right approaches, but synthesised it in an incorrect way?

Examples for Classifying Errors Using our Error Classification Scheme

To demonstrate the classification process as well as the universality of the scheme, we classify errors both from literature and from our own courses. As an example, we refer to the papers of Hristova *et al.* (2003), Sorva (2008) and Pea (1986).

- *Unbalanced brackets* (Hristova, Misra, Rutter, & Mercuri, 2003): This error is caused by sloppiness. Students usually know the answer if they have time and a less stressful situation. Thus, it is a MENTAL TYPO.

- *Java String is a primitive data type* (Sorva, 2008): This is a KNOWLEDGE GAP. Students learned a faulty definition, or did not learn the definition at all, even though they had been provided with the correct definition.

- *Not knowing the meaning of an object declaration* (Sorva, 2008): This is also a KNOWLEDGE GAP. Students are not able to remember the definition of a declaration.

- *Computer knows different lines at the same time* (Pea, 1986): This is a MISCONCEPTION as students have a faulty understanding of how a computer really works.

- *Code has more meaning than it actually has* (Pea, 1986): This is also a MISCONCEPTION, as students have a faulty understanding, which might originate from their human interaction experiences. The communication partner interprets much more than just the spoken words, such as facial expression, gesture and the context of the conversation. Thus, statements within a conversation are interpreted. If students transfer this understanding to a computer, they are not grasping the fact that a computer needs precise and self-contained instructions.

- *Only move the Sheep's body* (course): This is a MISCONCEPTION, too. Here, students are actually transferring their knowledge from everyday experience: If they move their body, the head and everything else follows automatically. In programming, this has to be explicitly expressed in the code.

- *Using while-loop-statement instead of if-statement* (course): In our courses, it sometimes happens that students use a while-loop-statement instead of an if-statement. They evaluate the condition and do something only once. In order to achieve this, they change the condition variable within the loop, so that the loop's body is executed only once. This is an error which belongs in the WRONG CHOICE category, as students decided to use an inappropriate construct, although he or she had already learned the appropriate one.

- *Not revealing the object structure* (course): In the assignment 'Sheep', many students just used the basic parts of the sheep and put them together in the main method, rather than hierarchically structuring them into more complex objects such as eyes or head. For example, eyes have an iris and a pupil. Correspondingly, a head includes nostrils, eyes and ears. Note that the required parts and their relationships were depicted in a UML-diagram. Nevertheless, students simply ignored these relationships. Therefore, this error is of type STRUCTURAL BLINDNESS.

- *20 conditions in if-statement instead of loop* (course): In our practical course, students used 20 conditions in an if-statement to check whether a word (with a maximum length of 40 characters) is a palindrome or not. Although the code worked fine, this is a bad programming style. Hence, students have a QUALITY GAP.

- *Duplicate code* (course): We mentioned above that students often have duplicate code in their programs. Classification schemes from literature do not cover this type of error. Within our schema, it is a QUALITY GAP. Although the produced code works correctly, it neither meets known quality standards, nor conforms with proven practice. As students already had lecture units on good programming style, they should have known better.

- *Not solving a problem* (course): One of our assignments had two parts, which were only slightly different. All the students solved the first part. Although the second part did not require any additional expert knowledge, only half of the students managed to solve the second task. The difficulty was that they had never had a similar task before. Hence, they were unable to develop a new solution. This indicates that students have a LACK OF INNOVATION.

Validation of the Error Classification Scheme

In the following, we list and explain typical errors made by novice programmers. The collection is based on six studies (Hristova, Misra, Rutter, & Mercuri, 2003; Pea, 1986; Sirkiä & Sorva, 2012; Sorva, 2008; Humbert, 2006a and 2006b; Rabel, 2011). Of course, many more papers on errors in programming exist, such as (Paul & Vahrenhold, 2013; Danielsiek, Paul, & Vahrenhold, 2012; Ahmadzadeh, Elliman, & Higgins, 2005; Kaczmarczyk, Petrick, East, & Herman, 2010; Holland, Griffiths, & Woodman, 1997; Goldman, Gross, Heeren, Herman, Loui, & Zilles, 2008; Giordano & Maiorana, 2014). However, to get an insight into students' thinking, these first mentioned six studies provide a sufficient overview. More precisely, the around 30 errors which were identified from these papers are sufficient for initially validating the classification schema that we introduced before. To unambiguously reference these errors throughout this work, we assign a unique number to each error, like <error no. 1>. An overview of all errors, their unique number as well as the assigned error class can be found in Table 4.

Population and Context of the Studies

Hristova *et al.* (2003) deal with relevant Java programming errors found in introductory courses. The authors collected errors based on reports of teaching assistants and from 58 schools in the US. They asked for the five most common programming errors and the "three hardest programming errors to find and/or fix given the compiler messages". Additionally, the authors collected data of students participating in undergraduate introductory Java courses. Errors found are divided into three categories: syntax errors, semantic errors, and logic errors.

The article of Pea (1986) talks about conceptual "bugs" in programming education. The author identified three classes of bugs: parallelism, intentionality, and egocentrism. It is suggested that all conceptual bugs are rooted in a "superbug". This "superbug" is described as the idea of a "hidden mind somewhere in the programming language that has intelligent interpretive powers".

Sirkiäs' and Sorvas' (2012) findings are based on an investigation on beginner programming students, using an educational program visualisation tool. They analysed the program logs of over 24,000 student-submitted solutions and tried to find errors students make in introductory programming classes. The authors came up with 26 errors which are relatively common. They categorised the errors found by: miscellaneous basic concepts, functions, and object oriented programming. In more detail, each exercise had a total number of simulation steps. The number of solutions handed in is in the hundreds.

The paper of Sorva (2008) deals with the understanding of basic programming concepts. During the analysis of student interviews three categories were found: understanding of primitive variables, understanding of object variables, and relationship between primitive and object variables. The programming language they focus on is Java. The study is based on 17 interviews carried out in spring 2007 and spring 2008.

Both publications of Humbert (2006a, 2006b) and Rabel (2011) focus on the secondary education, but did not provide any more specific information on the student population that was investigated.

Errors in Programming

Students sometimes confuse the assignment operator (=) with the comparison operator (==) (Hristova, Misra, Rutter, & Mercuri, 2003; Humbert, Informatische Bildung: Fehlvorstellungen und Standards, 2006) <error no. 1>. One problem that results from this error is unintended reassignment within conditional expressions. Furthermore, students modify conditional variables after evaluating the expression of an if-statement, or modify loop control variables after their evaluation (Sirkiä & Sorva, 2012) <error no. 2>. This error is aligned to the misuse of assignment and comparison operator.

Rabel (2011) and Sorva (2008) describe similar errors in their papers that will be called "always equal" later on. Rabel asked pupils to name the output of the print statements of the following code.

```
a = 5
b = 5 * a
print b # result: value of b is 25
a = 3
print b # result: value of b is still 25
```

Pupils answered the question with 15, 25 or "Does not work". The answers were equally distributed, so one third each. Hence, two third of the pupils did not know the correct answer. Furthermore, one third showed the erroneous assumption that a program works like a mathematical equation system <error no. 4>. This error is also reported by (Sirkiä & Sorva, 2012). The statement `b = 5 * a` will be evaluated again, when the value of 3 is assigned to a.

Sorva (Sorva, 2008) describes that in the context of primitive variables, students have an erroneous assumption that is indicated in the following code snippet:

```
int numberA = 0;
int numberB = numberA;
numberA = keyboard.nextInt();
int result = numberB + numberA;
```

If the value of one integer variable is assigned to another integer variable, like `number2 = number`, then these variables are assumed to be linked to each other. More specifically, `number2` contains a reference to the value of `number`. Consequently, if `number` changes, the value of `number2` will always change at the same time. This yields also to the following error. Some students reduce the last statement to `result = 2 * numberA, as numberB` has been set equal to `numberA` before. In the context of objects, the error of "always equal" variables also occurs (Sorva, 2008) <error no. 5>. These errors are summarised by the parallelism bug in the paper of Pea (1986). It is described as the assumption that a computer knows different lines in a program at the same time <error no. 3>.

Another error observed is a faulty string comparison (Hristova, Misra, Rutter, & Mercuri, 2003). Many students use `==` instead of `.equals` <error no. 6>. Thus, they compare the memory locations of two strings rather than matching their values.

Furthermore, Sirkiä and Sorva (2012) describe that students often try to assign the value of the variable on the left-hand side of an `=` to the variable on the right-hand side <error no. 7>.

Moreover, unbalanced brackets, parentheses and quotation marks are an issue <error no. 8>. Students mismatch, miscount and misuse them. Furthermore, they use different symbols interchangeably (Hristova, Misra, Rutter, & Mercuri, 2003). Additionally, novice programmers also tend to forget parentheses after a method call (Hristova, Misra, Rutter, & Mercuri, 2003) <error no. 9>.

As well, many students truncate important data by improper casting (Hristova, Misra, Rutter, & Mercuri, 2003) <error no. 10>. For example, novice programmers cannot distinguish between `int` and `float`. They believe that numbers are just numbers.

Novice programmers also invoke non-void methods, but do not store the return value (Hristova, Misra, Rutter, & Mercuri, 2003; Sirkiä & Sorva, 2012) <error no. 11>. Hence, the return value is lost. On the other hand, if they need the value, they compute the result again and again <error no. 12>. Furthermore, students create a variable called result to store e.g. the result of a calculation instead of returning the value (Sirkiä & Sorva, 2012). Hence, they cannot access the value later on because it is in another scope.

Another error is the intentionality bug (Pea, 1986). Students think that a program can foresee what will happen, or that it acts goal-oriented <error no. 13>. More specifically, "the program has goals, and knows or sees what will happen elsewhere in itself". However, this is not possible, as a program has a strict execution order and does not know what lies ahead. Nevertheless, students assume that a program has capacities or attributes of a human. Furthermore, they think a program has more information than given in the lines that are executed. Pea (1986) gives an example of a code in `BASIC` that draws a large square, and a medium-sized square inside this one, and so on. The dimension of the first square can be initially provided.

```
TO SHAPE: SIDE
IF: SIDE = 10 STOP
REPEAT 4 [FORWARD :SIDE RIGHT 90]
SHAPE: SIDE/2
END
```

Figure 3 shows the outcome of the program above. One square with a side length of 40 units is drawn. Afterwards, the side length is divided by 2 and another square is drawn inside. Then the side length is again divided in half. At the if-statement, the program stops, as side is equal to 10.

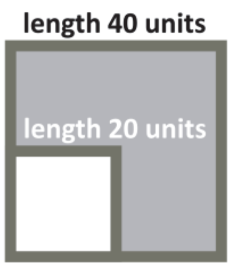

Figure 3: Outcome of the program.

The author asked students to think aloud about what the program is doing, when side was initially assigned the value 40. Some students read the if-statement this way: The program asks the computer to draw a square. Hence, the program foresees that the repeated statement of drawing a line, will end in a square. If my interpretation of the paper is correct, other students think that no square is drawn, because the program calculates that it will reach the value 10 later on. Thus, it stops immediately.

Egocentrism bugs (Pea, 1986) occur if students expect their code to reflect more of their original intention to fulfil the requirements, than what they actually coded <error no. 14>. More specifically, variable values or whole lines of code are omitted because of this bug. However, students think that the computer can fill in or knows the necessary values or parts, just as they are used to in conversations with fellow human beings. Here, one problem is that students would not say verbatim, that they expect their program to know the missing steps. Thus, they do not know that they have this bug in mind or act according to it. Students' attention is not guided to this problem as a relevant reason why their code does not implement the algorithm or process correctly. For example, some students explain the function of their `BASIC` code (see below) as follows: This code will draw a square:

```
REPEAT 4 [FORWARD 30]
```

However, for experienced programmers it is quite obvious that the turn command is missing, which would be required to arrange the drawn lines in the required right angles. Obviously, this program will only lead to a straight line with a length of 120 units. Nevertheless, students do not realize this. They act on the assumption that the computer can and will fill in the rest.

Sorva (2008) states the error that students are not able to explain a simple object declaration, like Player fourth; <error no. 15>. Moreover, students think that assigning an object to a new object copies the objects <error no. 16>, rather than copying the reference (Sirkiä & Sorva, 2012). This error is close to the observation that students cannot create a second object <error no. 17>. Rather, they make a copy of a reference to an already existing object instead of creating a new one (Sirkiä & Sorva, 2012). Another common error is that students create instance variables for new objects instead of just creating a local variable (Sirkiä & Sorva, 2012) <error no. 18>. In this case, students think that objects need to be part of the class and cannot just exist within a method.

Furthermore, students think of object variables as variables that contain multiple kinds of information of different types (Sorva, 2008) <error no. 19>. Additionally, several students treat an object variables' name as one of the object's properties (Sorva, 2008) <error no. 20>. This means that assignment changes an object's attributes, i.e. it is assumed that there exists a property that stores the name of the variable to which the object has been assigned to. This leads to the following assumption: If an object is assigned to another variable, the name property changes.

Hristova *et al.* (2003) states that students try to invoke class methods on objects directly <error no. 21>. Usually, a method is performed on a specific variable or object. However, class methods should not be invoked on objects.

Students sometimes think of primitive variables and object variables as two fundamentally different things (Sorva, 2008). If classes always contained instance variables of primitive types during lectures or in the teaching materials, this combination might lead to the opinion that instance variables cannot be object variables <error no. 22>. In short, students strictly distinguish between primitive and object variables. Additionally, they develop an idea that there are places in the code where only primitive or only object variables can be used <error no. 23>. One example is that instance variables can only be primitive variables. Other students think that object variables cannot be part of a method. They think that object variables are always part of a class. Additionally, Humbert (2006a, 2006b) describes the following errors: Pupils think of objects as a kind of variable <error no. 25>. Moreover, they tend to overemphasise the data aspect of objects compared to the behaviour aspect <error no. 24>. Most of these errors might develop from the way the concepts are taught and the kind of assignments within the lab sessions.

(Humbert, Informatische Bildung: Fehlvorstellungen und Standards, 2006; Humbert, Didaktik der Informatik - mit praxiserprobtem Unterrichtsmaterial, 2006) name the problem, that pupils often say if-loop instead of if-statement <error no. 26>. He thinks the cause is that if-statements and loops are taught in direct sequence. Hence, pupils cannot really distinguish between these two concepts. Another error that might be based on the way the concept is taught is introduced by Sorva (2008). The author notes that many Java programming novices think of Java String as a primitive type rather than an object <error no. 27>.

Table 4: Mapping Errors from Literature to Error Classes

Error		Error Class	Literature
1	Mixing = and ==	2	(Hristova, Misra, Rutter, & Mercuri, 2003) (Humbert, 2006)
2	Modify conditional variable after evaluation	5	(Sirkiä & Sorva, 2012)
3	Computer knows different lines at the same time	2	(Pea, 1986)
4	Code behaves in the same way as mathematical equation systems (not considering execution order)	2	(Rabel, 2011)
5	Assignment links variables (always equal)	2	(Sorva, 2008)
6	Faulty string comparison (== ↔ .equals)	2	(Hristova, Misra, Rutter, & Mercuri, 2003)
7	Assign left-hand variable to the right one	2	(Sirkiä & Sorva, 2012)
8	Unbalanced brackets, parentheses and quotation marks	0	(Hristova, Misra, Rutter, & Mercuri, 2003)
9	No parentheses after method call	0	(Hristova, Misra, Rutter, & Mercuri, 2003)

10	Improper casting	2	(Hristova, Misra, Rutter, & Mercuri, 2003)
11	Invoke non-void method and do not store return value	3	(Hristova, Misra, Rutter, & Mercuri, 2003)
12	Compute results again and again	5	(Sirkiä & Sorva, 2012)
13	Foresightedness of a program	2	(Pea, 1986)
14	Code has more meaning than it actually has	2	(Pea, 1986)
15	Not knowing the meaning of an object declaration	1	(Sorva, 2008)
16	Assigning object to new object variable means copying the data	2	(Sirkiä & Sorva, 2012)
17	Create new object by copying an object	2	(Sirkiä & Sorva, 2012)
18	Using instance variables instead of local variables	5	(Sirkiä & Sorva, 2012)
19	Object variables are variables that contain multiple kinds of information of different types	2	(Sorva, 2008)
20	Object variables' name is object property	2	(Sorva, 2008)
21	Invoke class methods on objects	1	(Hristova, Misra, Rutter, & Mercuri, 2003)
22	Instance variables can only be of a primitive type	1	(Sorva, 2008)
23	Special places in the code for primitive or object variables	2	(Sorva, 2008)
24	Overemphasis data aspect of objects	2	(Humbert, 2006)
25	Object is kind of variable	2	(Humbert, 2006)
26	Calling if-statement → if-loop	1	(Humbert, 2006)
27	Java String is a primitive data type	1	(Sorva, 2008)

Conclusion

Summing up, we first described an approach to find error clusters based on students' exam or assignment results. As a next step, we introduced our error classification scheme and applied this to classify these errors. Finally, we sketched the underlying causes of the observed error clusters.

The developed classification scheme is based on the well-known revised Bloom's taxonomy (Anderson, et al., 2001). We applied it for classifying errors that we observed in the process of computer science education. In addition, we mapped deficits to our teaching goals, as both are based on the same taxonomy. The resulting classification scheme is comprehensive and topic-independent. It is possible to classify all the errors found in literature and throughout our courses. As a set of examples, we classified around further 30 errors during our research.

A benefit of this scheme is that new errors can be classified by various people. Thus, it is not necessary to present a complete list of all possible errors. In our opinion, any person able to follow our classification process can classify errors. In order to verify this, we plan an empirical study, where different lecturers classify several errors. To evaluate whether our classification scheme is applicable in a more general way, in future work we will attempt to classify errors from other disciplines.

On the basis of our error classification scheme we can now explicitly create teaching goals that specifically address common errors. Currently, we are looking for existing interventions, as well as developing new ones, for each error class of the scheme. These interventions should focus on typical underlying deficits for each error class. Furthermore, interventions must be general enough to be appropriate for every error correctly classified in the corresponding class. The effectiveness of these interventions, as part of a whole approach of detection – classification – intervention, will also be evaluated.

References

Ahmadzadeh, M., Elliman, D., & Higgins, C. (2005). An Analysis of Patterns of Debugging Among Novice Computer Science Students. *ITiCSE.*

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., *et al.* (Eds.). (2001). *A Taxonomy for Learning, Teaching, and Assessing. A Revision of Bloom's Taxonomy of Educational Objectives* (1 ed.). New York: Longman.

Bahar, M. (2003). Misconceptions in Biology Education an Coneptual Change Strategies. *Educational Sciences: Theory & Practice, 3*, 55-64.

Bahar, M. (2003). Misconceptions in Biology Education and Coneptual Change Strategies. *Educational Sciences: Theory & Practice, 3*, 55-64.

Barke, H.-D. (2006). *Chemiedidaktik - Diagnose und Korrektur von Schülervorstellungen.* Springer.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher education, 32*(3), 347-364.

Danielsiek, H., Paul, W. & Vahrenhold, J. (2012). Detecting and Understanding Students' Misconceptions Related to Algorithms and Data Structures. *Proceedings* *of the 43rd ACM Technical Symposium on Computer Science Education* (pp. 21-26). New York, NY, USA: ACM.

Dictionary, O. E. (n.d.). Misconception. *Misconception*.

Dreesmann, D. C., Graf, D. & Witte, K. (2012). *Evolutionsbiologie - Moderne Themen für den Unterricht.* (S. B. Heidelberg, Ed.) Spektrum Akademischer Verlag.

Giordano, D. & Maiorana, F. (2014). Teaching "Design First" interleaved with Object Oriented Programming in a Software Engineering course. *Global Engineering Education Conference (EDUCON), 2014 IEEE.*

Goldman, K., Gross, P., Heeren, C., Herman, G. K., Loui, M. C., & Zilles. (2008). Identifying important and difficult concepts in introductory computing courses using a Delphi process. *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education.*

Herman, G. L., Kaczmarczyk, L., Loui, M. C. & Zilles, C. (2008). Proof by incomplete enumeration and other logical misconceptions. *Proceedings of the Fourth International Workshop on Computing Education Research.*

Holland, S., Griffiths, R. & Woodman, M. (1997). Avoiding Object misconceptions. *ACM SIGCSE Bulletin*, *29*, pp. 131-134.

Hristova, M., Misra, A., Rutter, M. & Mercuri, R. (2003). Identifying and Correcting Java Programming Errors for Introductory Computer Science Students. *Proceedings of the 34th SIGCSE Technical Symposium on Computer Science Education* (pp. 153-156). New York, NY, USA: ACM.

Humbert, L. (2006). *Didaktik der Informatik - mit praxiserprobtem Unterrichtsmaterial.* Teubner.

Humbert, L. (2006). Informatische Bildung: Fehlvorstellungen und Standards. *MWS -- Muensteraner Workshop zur Schulinformatik 2006*, (pp. 37-46).

Kaczmarczyk, L. C., Petrick, E. R., East, J. P., & Herman, G. L. (2010). Identifying Student Misconceptions of Programming. *Proceedings of the 41st ACM Technical Symposium on Computer Science Education* (pp. 107-111). New York, NY, USA: ACM.

Knuth, D. E. (1989). The errors of TEX. *Software: Practice and Experience, 19*(7), 607-685.

Paul, W., & Vahrenhold, J. (2013). Hunting High and Low: Instruments to Detect Misconceptions Related to Algorithms and Data Structures. *Proceeding of the 44th ACM Technical Symposium on Computer Science Education* (pp. 29-34). New York, NY, USA: ACM.

Pea, R. D. (1986). Language-independent conceptual "bugs" in novice programming. *Journal of Educational Computing Research, 2*, 25-36.

Rabel, M. (2011). Grundvorstellungen in der Informatik. *Informatik mit Kopf, Herz und Hand - Praxisbeiträge zur 14. GI-Fachtagung "Informatik und Schule" (INFOS2011)*, (pp. 61-70).

Sirkiä, T., & Sorva, J. (2012). Exploring Programming Misconceptions: An Analysis of Student Mistakes in Visual Program Simulation Exercises. *Proceedings of the 12th Koli Calling International Conference on Computing Education Research* (pp. 19-28). New York, NY, USA: ACM.

Sorva, J. (2008). The Same but Different - Students' Understandings of Primitive and Object Variables. *Proceedings of the 8th International Conference on Computing Education Research* (pp. 5-15). New York, NY, USA: ACM.

Thurner, V., & Böttcher, A. (2014). Devising and Producing a Teaching Video for Just-in-Time-Teaching. *European Conference of Software Engineering Education (ECSEE).*

Chapter 9

The Rubric: An Assessment Tool to Guide Students and Markers

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Abstract: The changing environment for both students and lecturers dictates the requirement for giving feedback on assessment activities rapidly. In order to close this cycle of learning for the student and facilitate the feed-forward process, the development of rubrics has become an essential part of the workload. The rubric tool needs to have clearly stated performance indicators and criteria so that both student and lecturer have the same expectations of the assessment activity. The rubric must be robust enough to be able to capture the balance of being both an easy tool for marking but also detailed enough to give constructive feedback reflecting the learning outcomes. The rubric development, given its complexity, when constructing this tool, can be time consuming but eventually becomes time saving. Thereby reducing the grading workload effort of the lecturer while maintaining the knowledge gained by the students through the assessment activity.

Keywords: Rubric; VLE; Performance Criteria; Feedback; Feedforward

Introduction

For the teaching and learning cycle, the word 'rubric' is understood generally to connote a simple assessment tool that describes levels of performance on a particular task and is used to assess outcomes in a variety of performance-based contexts' (Hafner and Hafner, 2003 p, 1509). The rubric as a marking tool and the virtual learning environment (VLE) have both worked their way into nursing education as 'new' way of teaching, learning and assessing students (Lai and Ng 2011). This allows both lecturer and student to develop as the facilitator and interpreter of knowledge and permitting clear ideas of what is expected from the assessment and what is achievable by the student. The rubric, unlike a marking template, is not only focused on giving guidance to marker but includes the student. With the marking templates there is greater capacity for and moreover, an inherent lack of uniformity and parity between markers, born out of each markers interpretation of the marking template. With the requirement of rapid turnaround times, transparent feedback to the student, combined with the ease of access via the VLE and the moderation process to be considered, a clear need has arisen to facilitate the marking process. The progressive movement of the use of technology and the easy access provided by online learning platforms, has created learning conditions where different aspects of feedback can be used (group, individual, audio), to ensure that the students learning is fluent and allows progression of the learning cycle.

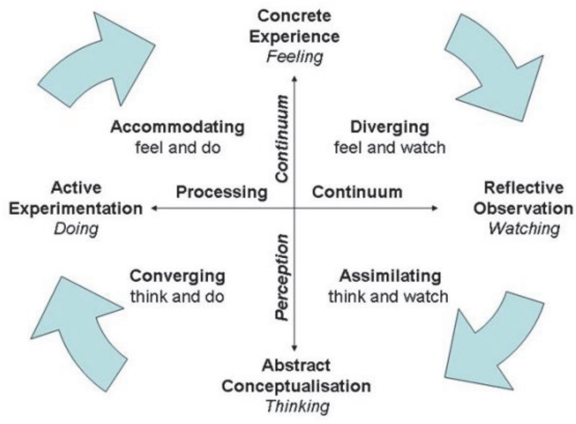

Figure 1 *Kolb's Learning Cycle*

The learning cycle

A rubric must be done right or must convey what you want to assess if not done correctly it diminishes the learning process which can have an impact on the learning cycle. McLeod (2014) perceives Kolb's learning cycle (Figure 1) as tool to identify the learner's style and how they retain information with a positive attitude towards the concepts being explored. In that vein the tutor therefore needs to visualise the type of rubric as a means to enhance that learning process to feedforward into the next stage of the learning experience. Within the three broad learning theories behaviourism, cognitivism, and constructivism all can be connected through the learning cycle via the rubric (Quinlan 2011). Bearing in mind when these theories were initiated, e-learning was limited or non-existent and distance learning was a paper based exercise. Due to many universities shift towards an e-assessment strategy, more work is required to be done online and both submission and feedback now occurs within the VLE. Hence making the learning process more efficient and succinct for the learner i.e. they do not have to leave the comfort of their home to engage with the learning materials nor do they have the added stress of travelling in to submit a piece of coursework. The importance of feed forward for feedback now has greater relevance due to the changing learning environment. Society has created a chaotic system, the impact of which has led to time constraints and has increased expectations of immediate response and feedback from the assessment task. This expectation has come about due to the access to twenty-four hour social media processes allowing instant responses in real time even though accessed via the virtual network maybe asynchronous. Therefore grading turnaround time has seen pressure to close the learning loop in a more immediate timeframe, such as the fifteen day feedback process, while maintaining high quality feedback. Hence if decreasing the turnaround time to assist the student's journey of learning the lecturer needs to be able to deliver said quality enhanced feedback for the student to close their learning cycle.

Marks-Maran (2014), opines that whilst for some higher education institutions the e-learning strategies and e-tivities are well embedded into the curriculum (an e-tivity being any online / electronic interaction within the VLE). For some institutions, this is not the case and remains a new phenomenon for those just embracing the capabilities of the VLE. Therefore 'new' is a slight misnomer as web based educational technology, strategies or the integration of learning e-tivities have become the norm for some, and have grown (Koch et al 2010); the rate at which assimilation of the e-assessment tools and e-learning occurs is variable from institution to institution hence the rate and pace of adoption and adaptation to e-marking and moderating is variable. What happens when these approaches are brought together? The focus here will be in part on the development, implementation and usage for all stakeholders involved in its utilization.

Combine the introduction of a new degree nursing curriculum in England (Nursing and Midwifery Council 2010), with the university's e-assessment strategy, and this brought an opportunity to review models of learning and teaching focussing on:-

1. How the student could engage in different ways of learning (e.g. Discussion boards, the flipped classroom, digital stories)
2. The capabilities of VLE (does it do what the lecturer wants?)
3. How best to facilitate submission and feedback within this environment.

The ideology behind the VLE is to create an engaging learning environment in which students can participate, while they are effectively developing 'clear thinking' and promoting an interactive learning experience (Lewis *et al.*, 2012). Therefore it is of paramount importance to give clear concise performance criteria and provide a forum in which students can create their own learning opportunities. Thus enabling the learner to build a genuine comprehension of the subject matter so they can foster confidence and research skills when conveying their ideas and opinions on a topic, (Pucer *et al.*, 2014). Given these criteria, it becomes imperative that both the lecturer and student have a clear understanding of the performance indicators, hence why the rubric was considered important tool. An important part of getting this right was to assure that students were assessed consistently and that all involved had the same expectations.

The considerations of creating a rubric

When starting to design a rubric, the main consideration is to know what type of rubric is required to reflect the type of assessment that is being scrutinised. The rubric is flexible enough to be used in different disciplines as each rubric is created to meet the learning outcomes in accordance with assessment task criteria set by the programme within which it sits. The assessment team need to consider how they build a relationship between the student and the rubric to enable it to become the vehicle for the learning journey which then in turn enhances the students engagement with the assessment (Belanger et al 2015). When evidencing these criteria with rubrics it is better to start small as in the simple rubric as shown in fig. 1, dependent on the assessment criteria. Thereby giving itself the versatility wanted by the marker in order to grade the task and measure the level of student engagement. So for example in rubric one the key point about that particular assessment task was ensuring engagement by the student in a different style of assessment unfamiliar to student whereas figure 5 is a generic essay rubric used throughout all academic years with some changes to reflect levels of academic requirements as is reflected in Bloom's taxonomy.

Moskal and Leyden (2000) states that the rubric needs to reflect what you want the rubric to assess; hence multiple assessment criteria would dictate that you would need different rubrics for different styles of assessments. The rubric can be categorized into three broad groups.

I. The first category is whether the rubric is going to be generic or task specific, this means if the rubric is going to be generic it can be used for multiple assessment task with no changes to the performance criteria and descriptors. Whereas task-specific is designed to focus on particular tasks with their criteria and descriptors reflecting the objectives of the assessment.

II. The second category is exploring the descriptors of performance, either as holistic or analytic. Holistic rubrics are the rubric that is designed with one general descriptor for the performance. Holistic rubrics require the assessor to give an overall score of the assessment these types of rubrics are usually used in assessments such a performances where there is not an absolute correct answer. Whereas, the analytic rubric has separate scores and individual performance criteria's that will judge each section of the assessment, then the sum of each of the sections will obtain the total score of the assessment. Airasian and Russell (2008) explain rubrics as one type of performance assessment: "A rubric is a set of clear expectations or criteria used to help teachers and students focus on what is valued in a subject, topic, or activity" (p. 223).

III. The third category is looking at distinguishing primary traits from multiple traits. Primary traits are task specific and evaluates performances based on only one characteristic whereas multiple traits evaluates performances based on several characteristics of a specific task when exploring these.

When designing an analytic rubric consideration needs to take place due to the fact that this type of rubrics is more time consuming to produce, as each performance criteria requires a description for each level, this gives the student more feedback and guidance of the assessments expectations The ideal number of performance criteria is between three (3) and six (6) as it does not overwhelm the memory and not so few that a distinguisher between the performance criteria cannot be made (Wolf and Steven 2007). Initially the authors started with a simple rubric (figure 2), but quickly found through student and staff feedback, combined with changing assessment from formative to summative, Rubric 1, was insufficient for the new task. Therefore an enhanced rubric was required with a greater number of performance indicators and criteria measurements. Wolf and Steven's (2007) guidance is supported by the writers, and have found that five (5) performance criteria have worked to great advantage when creating a qualitative and quantitative rubric (see Figure 3). This is to ensure that students have enough information to understand the assessment and that the feedback is concise whilst confirming that students are aware of what they are required to aim for in the next assessment.

Objective/Criteria	Performance Indicators	
	No	**Yes**
Meets word count requirement	(0 points)	(1 point)
Replied to 2 posts	(0 points)	(1 point)
Meets topic criteria	(0 points)	(1 point)
		out of 3

Figure 2 *Rubric 1.*

Once the rubric structure has been established then the development of the descriptors and performance indicators are decided. This need to reflect the learning objectives of the assessment task and therefore needs to clearly describe what the expectation is of the criteria being depicted. The validity of the rubric needs to support the appropriateness of the inferences that are made of the students responses for the assessment and the reliability of the rubrics is that the context is clear and the rubrics facilitate communication among students and provide the students, preceptors and faculty with language to foster feedback and discussion (Lasater, 2007). As nurse educators found it difficult to differentiate between levels of either academic or practice the variation of the different types of rubrics that can be design gives the assessor the ability to standardise the measurement of knowledge and behaviour of students. It is no secret that higher education, including nursing, is enjoying and is challenged by greater diversity of students related to characteristics such as ethnicity, gender, and experience (Lovegrove and Hatfield 2012. The rubric can provide a more level playing field for this increasingly diverse groups of students.

Objective/Criteria	Performance Indicators				
	Not Met (0 points)	**Satisfactory** (0.25 points)	**Good** (0.5 points)	**Very Good** (0.75 points)	**Excellent** (1 points)
Word count minimum of 250 words posted in THREE separate posts on THREE separate days	Does not meet minimum word count and/or posted all posts over 1/2 days	Meets minimum word allowance however did posts on two days	Meets word count minimum of 250 words posted 3 separate Posts on THREE separate days	Posted above word count minimum of 250 words posted 3+ separate posts on 3 separate days	Posted 3+ separate posts or above and exceeding the minimum 250 word count on 3/3+ separate days
Analyses and debates key concepts on the topic using literature to underpin arguments	Does not analyse and/or debate key concepts lack of literature to underpin arguments	Shows some ability to analyse and/or debate key concepts, lacks evidence in underpinning the concepts	Demonstrates some critical thinking and evidence of analyses with minimal evidence in drawing conclusions. Key concepts identified but not always relevant to the topic	Demonstrates critical thinking and analyses of the topic showing the beginning of evaluation and conclusions are drawn with the literature underpinning these statements	Analyses well and debates key concepts on the topic using literature to underpin arguments and validate concepts
Engaged in active discussion with at least two other students	Did not engage with discussion with two (2) other students.	Minimal to no engagement in discussion with two (2) or less students	Limited engagement with discussion and engaged with two (2) students	Engaged with two (2+) or more students in active discussion	Engaged in active discussion with 2+ students in leading debates
Contributed with topic and fellow students	Contributed minimally to the topic discussed and has not engaged fellow students.	Minimal contribution and understanding of the key principles of the topic	Demonstrate knowledge and understand of the key concepts and enhances fellow students understanding and contributions	Extensively contributed to topic and engaged well with fellow students	Extensively contributed to all concepts and engaged actively and in depth with fellow students
Use of appropriate language, grammar and MDX referencing	Inappropriate use of language, poor grammar referencing does meet MDX criterion.	Some inappropriate use of language and grammar. Careless attention to detail with MDX referencing	Appropriate language with some attention required in structure and adhering to MDX referencing	Appropriate and fluent use of grammar with minor mistakes in MDX referencing	Fluent use of language grammar and accurate MDX referencing and clearer attention to detail
Total: out of 5					

Figure 3 *Rubric 2 Complex*

The advantages and disadvantages of rubrics

Andrade and Du (2005) advocate that a rubric as an assessment tool should be used by the student and assessor to give both parties clear understanding of what is expected by either doing a task or grading the assessment. This aims to ensure achieving learning outcomes and activating a feed forward mechanism through concise information on how to improve performance whilst enabling student's time to reflect on their work (Truemper, 2005). This reflective ethos on work produced, fosters communication and the learning cycle to be completed.

There are many different debates surrounding the use of the rubric as an assessment and communication tool, the argument becomes clear that with the use of the tool greater parity occurs in grading. As well as the guidance of the performance indicators, it imparts explicit knowledge of what proficient means, this is evident from school age to higher education nursing and non-nursing education (Andrade and Du 2005; Caulfield-Sloan and Ruzcika; Hafner and Hafner 2003; Truemper 2004). Mandills et al (2009) support the use of rubrics in primary, secondary, further and higher education context as the grading is seen to be fairer and more consistent. Rubrics can useful in eliminating bias especially where anonymous marking is not in use, by not influencing the markers perception of the students' capability as they mark in accordance to the rubric (Shipman, 2012). Beaglehole (2014) focuses on students of school age children in Australia and encourages that clear and specific goals for writing are highly effective. While much is written on pre-university education rubrics and all VLE now appear to be offering either in-built grading systems or the ability to generate rubrics for units of learning, there is very little evidence of how its use is instituted or reviewed in the higher eduation sector.

Objective / Criteria	Performance Indicators				
	Not Met (0 points)	**Satisfactory** (0.25 points)	**Good** (0.5 points)	**Very Good** (0.75 points)	**Excellent** (1 points)
Word count minimum of all posts totalling 250 words, posted in THREE separate posts on THREE separate weeks	Does not meet minimum word count and/or posted all posts over 1/2 weeks	meets minimum word allowance however did posts on two weeks	Meets word count minimum of 250 words posted 3 separate posts on THREE separate weeks	Posted above word count minimum of 250 words posted 4 separate posts on 3 separate weeks	Posted 5+ relevant separate posts or above and exceeding the minimum word count over the three week period, on average 2 concise post per week
Analyses and debates key concepts on the topic using literature to underpin arguments	Does not analyse and/or debate key concepts lack of literature to underpin arguments	Shows some ability to analyse and/or debate key concepts, lacks evidence in underpinning the concepts	Demonstrates some logical thinking and evidence of debate with minimal evidence in drawing conclusions. Key concepts identified but not always relevant to the topic	Demonstrates logical thinking and debates of the topic showing the beginning of evaluation and conclusions are drawn with the literature/ evidence underpinning these statements	Analyses well and debates key concepts on the topic using current literature/ evidence to underpin arguments and validate concepts
Engaged in active discussion with at least two other students which develops debates and concepts	Did not engage with discussion with two (2) other students.	Minimal to no engagement in discussion with two (2) or less students	Limited engagement with discussion and engaged with two (2) students	Engaged with three (3) students in active discussion and developing debate and of concepts within the topic	Engaged in active discussion with four (4) or more students actively leading in the debates
Contributed with topic and fellow students	Contributed minimally to the topic discussed and has not engaged with fellow students.	Minimal contribution and understanding of the key principles of the topic discussed	Demonstrate knowledge and understanding of the key concepts. Enhances fellow students understanding and contributions to learning	Extensively contributed to topic and engaged well with fellow students in the learning process	Extensively contributed to all concepts and engaged actively and in depth with fellow students and acknowledge other approaches on the topic
Use of appropriate language, grammar and MDX referencing	Inappropriate use of language, poor grammar referencing does meet MDX criterion.	Some inappropriate use of language and grammar. Careless attention to detail with MDX referencing	Appropriate language with some attention required in structure and adhering to MDX referencing	Appropriate and fluent use of grammar with minor mistakes in MDX referencing	Fluent use of language grammar and accurate MDX referencing and clearer attention to detail

Figure 4. Rubric 3 Complex and Defined

The rubric as an assessment tool can be either presented as a simple rubric [yes /no performance indicators Figure 2], as was adopted, for example for a non-graded formative discussion board or as a complex rubric as was adopted, for example for a graded summative discussion board [descriptive banded performance indicators: unsatisfactory, pass, good, very good & excellent, Figure 3 & 4]. It should reflect the assessment learning outcomes (Popham, 1997) and should be presented with no confusion of the learning opportunity that needs to be taking place for the student (Vallino, 2008). Oppositely, for the marker the rubric should be a tool that ultimately relies on the ability, knowledge and preparation of the assessor and will be enhanced with the familiarity of ``the performance criteria´´.

Each new academic year is dependent on staff and student feedback, giving rise to the rubric being refined to give greater clarity each time it is used, therefore becoming an animate grading tool (see figure 4). The other advantage of the rubric when marking is its focus on the specific criteria that the students have to attain for the module (Truemper, 2003). Fors & Gunning, 2014, suggests that the rubric needs to present a clear set of assignment descriptions/categories and have levels of performance indicators that are the evaluation dimension which may or may not hold numerical and Petkov, 2006) and can be used either online in the VLE or in the classroom face to face. A rubric is only as good as its design, support and explanation in its use. Conversely the expectations from the use of the rubric should enhance the learning outcomes for the students. Without this, a rubric can lead to promotion of shallow learning whilst producing conformity and standardisation in the VLE, (Mansilla et al., 2009). In turn this can create missed learning opportunities for the student as they are only working towards the rubric criteria. There are some criticisms of the use of rubrics in regards to ‘validity, reliability and fairness’ particularly in relation to students in view of a lack of empirical evidence to support effective use of a rubric, (Andrade & Du, 2005 p 29). Jonsson and Svingby, 2007, propose that effectiveness of rubrics can be examined based on literature at the time of writing. Despite these on-going issues there is growing confidence about the effectiveness of rubrics (Rezaei & Lovorn 2010).

When developing a rubric the lecturer needs to consider the type of assessment being designed for example an essay, or a learning log, or annotated bibliography, or discussion board, or a poster, the lecturers need to investigate whether there is already a marking guide on which to base the rubric. Hence in development of the rubric, Nicol and Mcfarlen–Dick’s, 2006, seven principles of good feedback should implement:-

1. Clarify what good performance is
2. Facilitate reflection and self-assessment in learning
3. Deliver high-quality feedback information that helps learners self-correct
4. Encourage teacher–learner and peer dialogue
5. Encourage positive motivational beliefs and self-esteem
6. Provide opportunities to act on feedback
7. Use of feedback to improve teaching

It should be simple to use and the language of the performance indicators should be easily understood by both the lecturers and students (Whittaker, Salend & Duhaney, 2001; Wilson & Fairchild, 2011). To promote this effect it is critical that the language used in the performance indicators and the categories is transparent and there is no misconception of what is expected from the learning outcomes (Lasater, 2006). Other contributing factors to consider is how the rubric is intended to be used as a feedback mechanism for students, and thereby to continue to improve their comprehension and expectation of the assessment activity (Morgaine, 2010). When using the rubric as a grading tool and to elicit the engagement of the students through understanding the assessment activity requirements, the main reference to the rubrics for both parties are the differing criteria for each of the performance indicators. These categories have to be accurately represented and achievable. The communication that the rubric gives enables the students to engage in assessment activity. Hence the use of the language within the rubric must foster a dialogue that works in partnership with the feedback and promotes discussion between the lecturer and the student. Stevens and Levi (2005) sees the rubric as a translator device to gain a level playing field in the learning activity.

The goal of the developing rubric, is to create equal opportunities for the students when engaging with the assessment process and receiving feedback from the lecturer. A result of the changed the learning environment via the VLE for students is to have a constructive influence on student engagement. The VLE gives easy student home-based access with the benefits of developing critical thinking with socialised interaction with others in a learning space (Buckley, et al 2005). As lecturers, there is a need and basic requirement in most UK universities to mark and moderate work within a fifteen working day turnaround period and feedback to the student. This becomes increasingly important in multiple assessment orientated modules, where each assessment is graded separately all feeding into the final summative grade. Students therefore require clear feed forward guidance to improve and enhance their writing and communication skills not only for the current assessment but all aspects of their academic and professional life were ‘higher order thinking process’ (Jonnson and Svingby 2007 p 31) are required. Hence the challenge becomes to ensure quality accelerated feedback (Saddler and Andrade 2004) to close the learning loop.

Criteria	Weighting %	Comments			
Breadth, depth and focus of content in relation to the question set for essay/exam and learning outcomes for the module	/20	18-20%	15-17%	12-14%	0-11%
		- Answer clearly relevant to the question, in breadth, depth and focus of content -Clearly meets all learning outcomes	- Content of answer reflects good breadth, depth – greater exploration of issues and focus of question. - Meets learning outcomes	-- Content of answer partially reflects question. - Partially meets learning outcomes	- Limited relevance to the question and practice, where requested. - Does not meet learning outcomes - lacks clear focus
Knowledge and understanding of module content applied competently to the essay/exam showing ability to analyse relevant debates, models and arguments.	/35	30-35%	21-29%	11-20%	0-10%
		- Well-integrated answer with clear evidence of analysis/synthesis, and evaluation relevant to the question. -Demonstrates very good ability to analyse relevant debates, models and arguments.	- Integrated answer with some evidence of critical analysis /synthesis, and a good attempt at evaluation though not always relevant to the question. - Demonstrates ability to analyse relevant debates, models and arguments.	- Shows some critical thinking and the beginnings of synthesis and evaluation. - Demonstrates some ability to analyse relevant debates, models and arguments. -Clear rationale in places but needs to be consistent throughout assignment	- Wholly or mainly descriptive - Poor ability to analyse relevant debates, models and arguments. -Lacks evidence based practice to underpin statements
Commentary/discussion shows application of theory to practice utilising effectively evidence/research from a range of relevant sources to show safe clinical practice.	/35	30-35%	21-29%	12-20%	0-11%
		- Demonstrates very good knowledge and understanding with application and integration of knowledge to practice where requested. - Clear appropriate rationale	Demonstrates knowledge and understanding and some application to practice, where requested.	Demonstrates some knowledge and understanding. Limited application to practice, from a small range of resources.	Demonstrates no / limited knowledge and understanding Little / no application to practice. -Needs a clear rationale that is followed up throughout assignment
Presentation and organisation of work. Referencing system complies with the HAE Referencing and Citation style	/10	9-10%	7-8%	5-6%	0-4%
		- Well structured and organised. - Relevant arguments presented and addressed -Well concluded. - All key sources cited and used effectively to support answer/arguments. - complies with the HAE Referencing and Citation style	- Good structure, presentation and coherently expressed. - Widely discussed in some areas - Some attempt to conclude answer. - Answer demonstrates good use of a moderate range of sources to support answer/arguments. - Referencing system complies with the HAE Referencing and Citation style, minor errors	- Some attention paid to the structure and organisation/ coherence. -Starts off well but deteriorates towards the end - Evidence of discussion. - Conclusion limited - Few but relevant sources used to support answer/arguments. - Referencing does not wholly comply with the HAE Referencing and Citation style	- Poor organisation and structure. - Lacks /limited discussion. - No /limited referencing - Lacks a conclusion - Little/no use of key sources to adequately support answer/arguments. - Referencing system does not comply with the HAE Referencing and Citation style

Figure 5 *Example of a generic rubric*

Rubric review and revision

A key positive outcome for the lecturers when using the rubric is that the tool should be user friendly, becoming easier to identify the different grading scales that correlate with the performance indicators. This simplifies the marking experience speeding up the process whilst enabling the giving of constructive feedback in a timely fashion. It also minimizes the inconsistencies between lecturers and gaining parity in the assessment process. Looking at students comments received at the end of the academic year, the rubric evolved. From the students perspective there were mixed feelings dependent on the result they received (see figure 6). It was clear that many students could see the benefits of the rubric and used this as a tool to guide themselves when preparing academic work for submissions. It gave them a greater sense of guidance backed up by the module study guide. It was also clear that while specific rubrics with definitive mark allocations were easier to comprehend on the behalf of the student, whereas generic descriptive rubrics with a variable scale within performance indicators caused confusion as to how the mark was allocated. The students like clear processes and because of the variety marks it was difficult for the student to understand the differences within a banding.

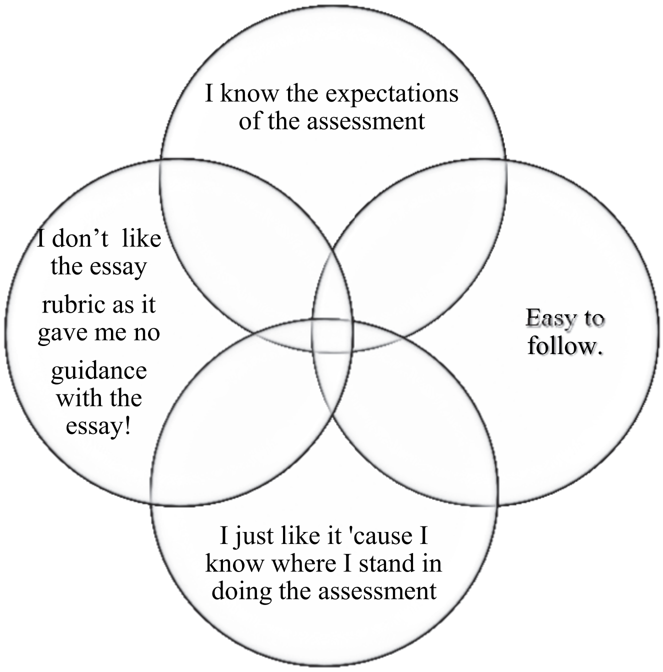

Figure 6 *Students Perspective*

The team noticed there were more challenges to the grades given but also observed greater parity between markers. It was easier when giving one to one feedback to show the student where and why a grade was or was not given. There was clear delineation between bandings and where some descriptors were lacking, the team reviewed the bandings and modified feedback descriptor. In particular where they felt the rubric was lacking or the performance indicator did not allow for the mark they wanted to allocate and hence could not demonstrate this adequately to the student. As Sparrow (2004) rightly states you cannot introduce the use of a rubric without first explaining its purpose and function for the academic and the student. Initially the rubric was not met with enthusiasm but with usage some members have changed their perspective on its usefulness and role with the grading system. It encouraged tutor's on other modules to develop rubrics to fit their assessment criteria. Discussion with tutors new to marking as well as those who have years of experience has brought to light a liking for the use of rubrics (see figure 7). New tutors reported back the removal of stress and

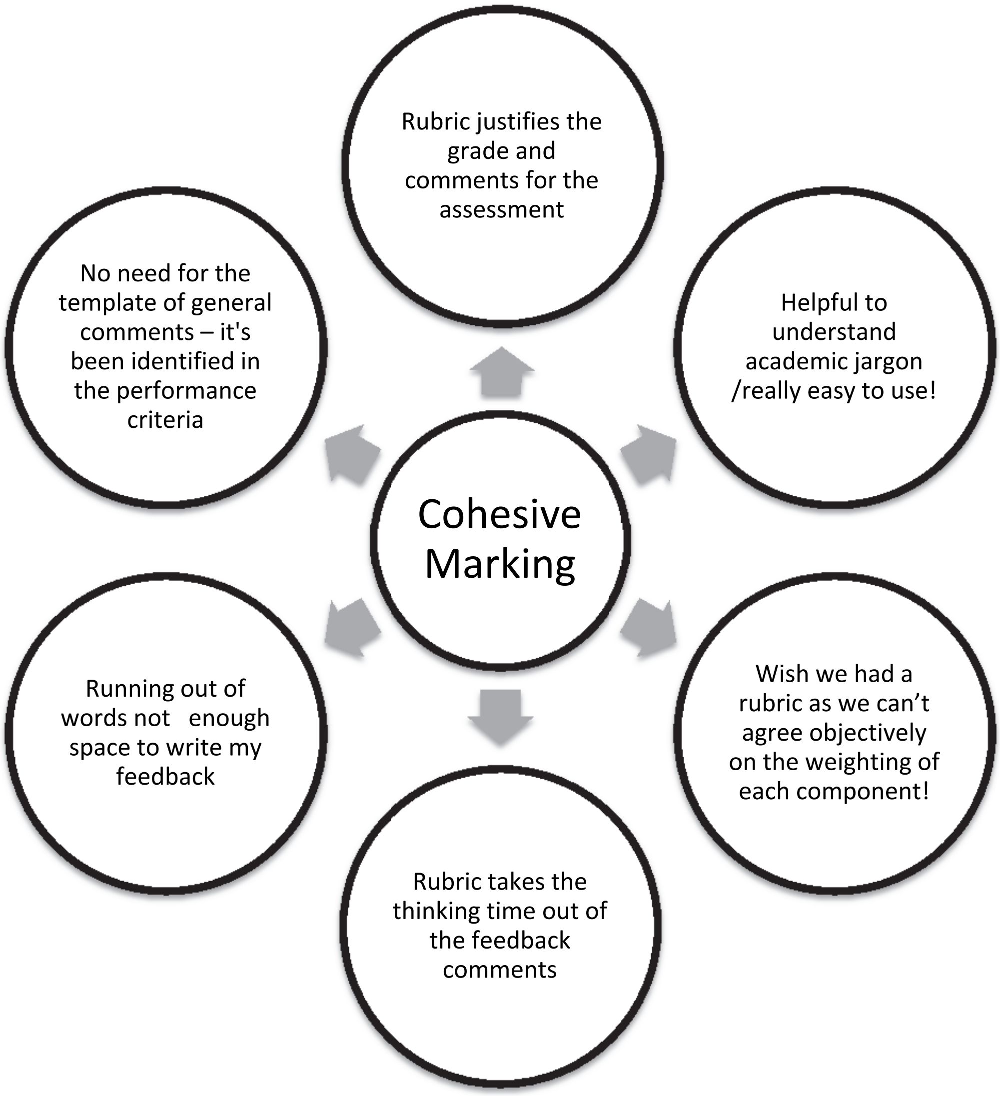

Figure 7 *Tutors Perspective*

anxiety when doing their first piece of grading the rubric supported their own validation of the grade/mark they wanted to give the student. The performance indicators validated their comments in the free text. While experienced tutors reported either wanting to have a rubric versus never used one before and saw the benefits of ease of access in completing quality feedback in a timely fashion.

For tutors not enamoured with rubrics they saw them as being didactic and inflexible taking away their autonomy in allocating marks. This could be due to having to justify why they have given a set of marks and a lack of control due to the rubric performance criteria banding the students work. Some lecturers have the perception that by grading using the rubric which is pre-released prior to submission to the student's advantages them and is equivalent to cheating and not seeing it as tool of learning. But this negative could be seen as a positive as in some cases this gave the teaching team greater parity among markers. Morgaine (2010, p11) advocates that lecturers must learn to conduct assessment not only within a group but as a group; they must share knowledge, reflect upon expected outcomes, build consensus and take collective ownership of the assessment. The rubric forces the lecturer to clarify the criteria, reduce the time to evaluate the work and provide useful feedback.

What makes a quality rubric?

Rubrics are almost always a work in progress and most have strengths and weaknesses. As a result, a rubric designed for one purpose may display a good quality for one particular aspect of the learning goal but could be an exemplar quality for a different attribute. Conversely some of the quality examples which work for one style of rubric may not capture the essence of task being assessed in another rubric. It may hinder the learning outcomes of the assessment for the student and skew the feedback for the student and the lecturer causing miscommunication or misinterpretation of the concepts that were to be achieved within this learning assessment process. Using a rubric as a tool to explore how to attend to the minutiae of the assessment, would act to ensure that any one rubric is clear, explicit and effective. A poorly designed rubric will not assist the student in identifying or improving the quality of their work in relation to the information from the performances indicators from one banding to another. If you improve these qualities the rubric becomes a powerful and useful tool to close the learning cycle whereby increasing the students ability of being able to self-assess the quality of their work without waiting for lecturers feedback.

Therefore to produce a quality rubric it needs to include the following components; while the rubric does not necessarily need to be presented in a table format the key attributes should be included to capture the purpose of the assessment. The content of each cell should explain the degree of quality within a performance indicator level. The dimensions in an analytical rubric need to be a breakdown of the tasks components. The rubric needs to show progression from low to high in articulating the degree to which the student has demonstrated meeting the learning outcome criteria of the assessment. The tone and nature of the language used to describe each characteristic is important in communicating the expectation of the performance indicator, informing the quality of that indicator required and in turn the level of engagement needed to attain that criterion. Lastly the physical appearance of the rubric itself needs to be engaging, easy to follow, clear, concise and succinct.

Conclusion

In today's educational environment, the student wants clear guidance and direction to "how is this assessment being graded?" and "what is it that the assessment is asking for?” In return there are increasingly more expectations on the lecturer to engage with a variety of different modes of assessment and to enhance the learning experience of the student. In real terms this means rapid marking and feedback to be ready in a short time frame, therefore the use of a rubric for this purpose is a tool that can facilitate this. However to design an effective rubric requires time and revaluation after each usage. Each rubric should be designed individually to reflect the assessment activity. When starting out it is easier to start simple rather than complex as the road travelled for the rubric is about meeting the needs of the lecturer and the student. The rubric is a grading tool that should communicate the expectation of the assessment activity and use as constructive feedback for the student to feed-forward with the learning concepts obtained from the assessment task.

The performance levels indicators must enable both the lecturer and student to differentiate between levels. Hence the description of these levels needs to be clearly defined and logically sequenced. It should promote recognition of varying levels of performance and encouraging the student to improve and drive own learning to enhance their depth of knowledge. This can be further achieved through the ability to discriminate between performance levels via the use of a range of subjective words in defining these differences. The specificity of the performance indicators needs to demonstrate usefulness, and allow enhanced analysis of the given task.

The development [see Figures 2, 3 and 4] of this rubric was to facilitate fast and effective feedback to feed forward for an online discussion board. It was a way of ensuring that both lecturer and student understood what was required of them. This style of analytic rubric provided the potential for the student to take accountability for their own learning through clear performance criteria. By combining the assessment outcomes with the performance indicators the rubric has been able to provide the students with information regarding what is most important to focus on and where their level and depth of knowledge is in relation to the given assessment. Through reviewing students work and the original rubric against the developing rubric other additional criteria are generated or deleted. Therefore this triggered another revision of the rubric which concentrated on the finer differentiation of levels (see Figure 4).

When evaluating the assessment it is always useful to review the rubric. All rubrics share common themes of usefulness, performance levels and demonstrative words. The performance levels indicators must enable both the lecturer and student to differentiate between levels. Hence the description of these levels needs to be clearly defined and logically sequenced. It should promote recognition of varying levels of performance and encouraging the student to improve and drive own learning to enhance their depth of knowledge. This can be further achieved through the ability to discriminate between performance levels via the use of a range of subjective words in defining these differences. The specificity of the performance indicators needs to demonstrate usefulness, and allow enhanced analysis of the given task.

How the rubric continues to develop will be dictated by its utilisation and the revision/evaluation process. The teacher designed rubric needs to evolve with each usage, as the feedback that is generated for students changes as the students find new innovative approaches that cannot be anticipated when the students undertake the assessment. This could be due to the familiarity that the rubrics have now been embedded into the student's learning styles and approaches. The changing environment of the VLE also dictates the alterations of the rubric to accommodate the platform that it is being embedded into. This enables the learning process and feedback mechanism to be a fluid assessment tool responding to changes as they occur. Once the student acquires and understands the fundamentals of the learning goal to be achieved the student becomes a strategic learner and will learn to use the knowledge to play to the assessment strengths. Therefore it should be acknowledged that the rubric is not a static tool but an implement that is continually evolving and enhancing the learning process.

References

Airasian, P. W. & Russell, M. K. (2008). Classroom assessment: Concepts and applications (6th ed.). New York: McGraw-Hill.

Andrade, H., (2005). Teaching with rubrics the good, the bad, and the ugly. College Teaching, 53(1), 27-30.

Andrade, H., Du, Y., (2005). Student perspectives on rubric-referenced assessment. Practical Assessment Research and Evaluation, 10(3), 1-11.

Belanger, J., Zou, N., Rushing Mills, J., Holmes, C., Oakleaf, M., (2015) Project RAILS: Lessons Learned about Rubric Assessment of Information Literacy Skills. Portal: Libraries and the Academy, 15(4), 623-644.

Beaglehole, V. (2014) Assessing Writing Using rubrics. Practically Primary. Practically Primary, 19(2), 13-15.

Buckley, K.M., Benya, B., Dudley-Brown, S., (2005). Promoting active learning through on-line discussion board. Nurse Educator, 30(1), 35-36.

Burke, D., Pieterick, J., (2010) Giving Students Effective Written Feedback, McGraw-Hill Education.

Caulfield-Sloan, M.B., Ruzicka M.F., (2005). The Effect of teachers' staff development in the use of higher-order questioning strategies on third grade students' rubric science assessment performance. Planning and Changes, 36(3-4), 157 – 175.

Dunbar, N, E., Brooks, C.F., Kubicka-Miller, T., (2006). Oral communication skills in higher education: Using a performance-based Evaluation Rubric to assess communication skills. Innovation Higher Education, 23(2), 115-127.

Fors, U.G.H., Gunning, W.T., (2014). The impact of different scoring rubrics for grading virtual patient – based exams. Journal Education Computing Research, 50(1), 97-119.

Hafner, J., Hafner, P., (2003). Quantitative analysis of the rubric as an assessment tool: an empirical study of student peer-group rating. International Journal of Science Education, 25(12), 1509-1528.

Jonsson, A., Svingby. G., (2007). The use of scoring rubrics: Reliability, validity and educational consequences. Educational Research Review, 2, 130-144.

Koch, J., Andrews, S., Salamonson, Y., Everett, B., Davidson, P.M., (2010). Nursing students perception of a web based intervention to support learning. Nurse Education Today, 30, 584 – 590.

Lai, Y.C., Ng, E., M, W., (2012). Using Wikis to develop students teachers' learning, teaching and assessment capabilities. Internet and Higher Education, 14, 15 – 26.

Lasater, K., (2007). Clinical Judgment Development: Using Simulation to Create an Assessment Rubric. Journal of Nursing Education, 46(11), 496 - 503.

Mansilla, V.B., Duraisingh, E.D., Wofle, C.R., and Haynes, C., (2009). Targeted assessment rubric: An empirically grounded rubric for interdisciplinary writing. The Journal of Higher Education, 80(3), 334-353.

Marks-Maran, D. J., (2014). Using an innovative evaluation research framework: A case study into the evaluation of perceptions of a preceptorship programme. Networking for Education in healthcare, international (NET, INT) Conference. Holland.

McLeod, S. A. (2013). Kolb - Learning Styles. Retrieved from www.simplypsychology.org/learning-kolb.html.

Morgaine, W., (2010). Developing Rubrics: lessons learned; Assessing Outcomes and Improving: Tips and tools for Using Rubrics, 11-13. Chicago.

Moskal, B. M., Leydens, J.A., (200). Scoring rubric development: validity and reliability. Practical Assessment, Research & Evaluation 7(10). Retrieved August 4, 2015 from http://PAREonline.net/gettn.asp?v=7&n=10.

Nicol, D.J., Macfarlane-Dick, D., (2006). 'Formative assessment and self-regulated learning: A model and seven principles of good feedback practice', Studies in Higher Education, 31(2), 199–218.

Nursing and Midwifery Council. (2010). Standards for pre-registration education.

Petkov, D., Petkova, O., (2006). Development of Scoring Rubrics for IS projects as an assessment tool. Information Science and Technology 3, 500 – 509.

Popham, W.J., (1997). What's Wrong - and What's Right- With Rubrics Educational Leadership, 55, 72- 75.

Pucer, P., Trobec, C.I., Zvanut, B., (2014). An information on communication. Technology based approach for acquisition of critical thinking skills. Nursing Education Today, 34 (6) 964-970.

Quinlan A. M., (2011) A Complete Guide to Rubrics: Assessment Made Easy for Teachers of K-college 2nd edition, Rowman & Littlefield Education.

Reddy, Y.M., Andrade, H., (2009). A review of rubric in higher education. Assessment and Evaluation in Higher Education, 35 (4) 435-448.

Rezaei, A.R., Lovorn, M., (2010). Reliability and validity of rubric for assessment through writing. Assessing Writing, 15, 18 -39.

Sadler, B., Andrade, H., (2004). The Writing Rubric. Educational Leadership, 62 (2), 48-52 .

Shipman, D., Roa, M., Hooten, J., Wang, Z.J., (2012). Using the analytic rubric as an evaluation tool in nursing education: The Positive and the negative, Nurse Education Today, 32, 246-249.

Song, L., McNary, S.W., (2011). Understanding Students' Online Interaction: Analysis of Discussion Board Postings. Journal of Interactive Online Learning 10 (1) 1-14.

Sparrow, S. M., (2004) Describing the Ball: Improving Teaching by Using Rubrics- Explicit Grading criteria Michigan State Law Review 2004:1, 1-56.

Stevens, D.D., Levi, A., (2005). Introduction to Rubrics. An assessment tool to save grading time, convey effective feedback and promote student learning. Stylus Publishing, LLC. Virginia.

Truemper, C.M., (2004). Using scoring rubrics to facilitate assessment and evaluation of graduate level nursing students. Journal of Nursing Education, 43, (12) 562-4.

Vallino, J., (2008). Workshop- Rubrics: Start to Finish. Proceedings of 2008 Frontiers in Education Conference, Saratoga Springs, NY.

Whittaker, C.R., Salend, S.J., Duhaney, D., (2001). Creating instructional rubrics for inclusive classrooms. Teaching Exceptional Children, 34(2), 8-13.

Wilson, M., Fairchild, C., (2011). Collaborative learning and the importance of the discussion board. Journal of Diagnostic Medical Sonography, 27(1), 45-51.

Wolf K. & Ellen Stevens (2007). The Role of Rubrics in Advancing and Assessing Student Learning. University of Colorado at Denver and Health Sciences Center The Journal of Effective Teaching, Vol. 7, No. 1, 2007 3-14.

Wu, X.V., Heng M. A., Wang W., (2015). Nursing students' experiences with the use of authentic assessment rubric and case approach in the clinical laboratories Nurse Education Today, 35, 549-555.

PART III

Resource creation

Chapter 10

Developing Incentives for the Use of Open Educational Resources in Higher Education

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Abstract: This chapter outlines characteristics of Open Educational Resources (OERs), and the challenges that discourage their widespread development and use in higher education. Development of an OER within one institution is described, including the financial incentives that provided the impetus for the project. Originally conceived almost twenty years ago as a means to reduce institutional costs, the project has evolved to the point where a large amount of comprehensive learning material is freely accessible, sharable, adaptable, and reusable under a Creative Commons licence. The case study suggests a relatively straightforward change that is needed in most higher education jurisdictions to encourage the widespread use of OERs and align the financial interests of government, institutional administrators, faculty members, and students. Specifically, higher education institutions should be required to include the cost of all learning materials in tuition fees charged to students. Undesirable effects of the current system on the use of OERs are discussed, as well as the positive effects of the suggested policy.

Keywords: Open educational resources; financial incentives; educational barriers

Introduction

One of the more remarkable educational developments in the 21st century is the growing use of open educational resources (OERs) as a means to freely share, adapt, combine, extract, and generally propagate knowledge in formal and non-formal settings. The Paris OER declaration (UNESCO, 2012) stated that " . . . the term Open Educational Resources designates teaching, learning and research materials in any medium, digital or otherwise, that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" (p. 1). In addition to learning content, two other components are necessary to produce effective open educational resources: the technological means to support the development, adaptation, and distribution of the learning content, and "implementation tools" – the legal and regulatory framework that permits varying degrees of control over content (CERI 2007, pp. 31-32). Chief among these tools is the rapidly-growing use of open licensing systems, particularly Creative Commons (CC). Put simply, an open educational resource is learning material that is licensed to facilitate its reuse, adaptation, and redistribution with no or limited restrictions. In the context of this chapter, the discussion is also limited to a formal higher-learning context.

The purpose of this chapter is to briefly describe the characteristics of OERs, identify obstacles to their greater use within higher education, and describe the financial benefits in particular that accrued to one university through the development of a comprehensive OER resource. From this case study, a relatively simple change to the predominant funding model for higher education is proposed that would encourage the systematic use of OERs, with net benefits accruing to governments, institutions of higher learning, and students.

Overview of Open Educational Resources

There are important differences between OERs and related concepts. First, OERs are not synonymous with open learning. Open learning assumes not only the use of OERs as instructional material, but also the use of assessment and accreditation systems, formalized learner support, rather complete curricula, and the means to assess prior learning. Second, OERs are not the same as resource-based learning. OERs are only one part of resource-based learning, the main impetus of which is to produce a shift away from predominantly face-to-face knowledge transmission models like lectures to types of more student-centred learning like "flipped classrooms". Third, OERs specifically refer to teaching and learning materials and thus differ from open publishing. Open publishing provides free access to mainly scholarly publications and research, though these can be incorporated into OER for pedagogic purposes. Lastly, though OERs can be an integral part of online learning, the concepts are different. OERs are often available in both print and digital media, and can be utilized in a wider variety of educational settings (Butcher, 2015).

There are strong financial arguments for the production and use of OERs. Proponents argue that the state pays less overall when students can use OERs instead of purchased textbooks. Lower learning material costs reduce the amount of debt that students must assume to complete their education. Therefore, the available pool of state aid in the form of bursaries and subsidized student loans goes further, and loan default rates are lower. The state and society benefit in a number of indirect ways as well. More students are able to participate in higher education when overall costs are reduced. Better educational outcomes result when more students are able to afford and therefore actually obtain the texts required for their courses. These desirable outcomes could help equalize worldwide access to education. The large, positive effects for society are the main reason why a growing number of projects funded by governments and private philanthropy seek to identify, evaluate, and fund the development of OERs.

There are examples of successful OER implementation projects in higher education, like the Open Education Consortium at MIT and OpenStax College established by Rice University. Others include the Washington State Board of Community and Technical College's Open Course Library project (Butcher and Hoosen, 2012) and the OpenLearn project undertaken by the Open University of the United Kingdom (Gourley and Lane, 2009). However, each of these projects receives institutional support and large amounts of internal funding, primarily because they provide significant marketing benefits to the applicable university. This in turn helps the student recruitment process. The institutions were also the first entrants into the market, well known, and offered a relatively complete range of products. In general there is a notable lack of broad-based initiatives among non-elite higher education institutions (Wiley and Gurrell, 2009). Some reasons for this are discussed below.

Obstacles to OER Development and Use

There are several constraints on OERs that limit their use in the academy. Academics often have reservations about their overall quality, and fear loss of control over intellectual property. As well, a perception persists that too much effort is required to locate and evaluate material, and that faculty lack the technical skills to do this (Allen & Seaman, 2014; Armellini & Nie, 2013; Bossu & Tynan, 2011; Okonkwo, 2012; Plotkin, 2010; Sclater, 2010).

But the most significant barrier to sustainable OER production and use appears to be financial. Though freely distributable, OERs are not costless. The time needed to produce, or to find and adapt OERs must be taken into account. There may be costs involved to ensure that copyright compliance and mandated accessibility standards are met. Technological infrastructure for production and distribution needs to be supported. An OER initiative may be sustainable for a particular institution to the extent that it attracts new students, facilitates more transparent accountability of taxpayer funds, fulfils its public service role, or advances the institution's reputation. However, these uncertain or intangible benefits have little direct financial reward (Daniel and Uvalić-Trumbić, 2011). Against these benefits, actual financial costs must be considered. Bates (2015) estimated that a relatively complete OER suitable for one semester-length course would cost about €100,000 if all outlays are considered.

Lack of ongoing funding to cover these costs is commonplace. In his analysis of repository failings until 2008, Friesen (2009) observed that almost none survived beyond two or three years, and that this coincided with the usual span of start-up grants. The same appears to be true for OER production and use. A critical issue for any OER project is its sustainability, and this implies access to long-term, reliable funding (Wiley and Gurrell, 2009; Barrett, Grover, Janowski, van Lavierena, Ojoa, and Schmidta, 2009; Atkins, Brown, and Hammond, 2007).

Downes & Dholakia (2007), King & Baraniuk (2006) described several kinds of funding models. However, none of these anticipated that OER projects could generate self-sustaining revenues. The literature assumes that there are only a limited number of feasible alternatives: mainly, governments can provide targeted funds for OER production and use; or educational institutions can encourage inter-institution collaboration and provide incentives for faculty development of OERs (Daniel & Uvalić-Trumbić; 2011, de Langen, 2012; Muller, 2013; Stacey, 2010).

However, these alternatives are problematic. Obtaining continued external funding to cover OER production costs by a particular educational institution is tenuous, and requires ongoing competition for limited government or private philanthropic subsidies. Additionally, both philanthropists and the state still need to invest additional funds, or re-deploy scarce resources. It is not clear why a choice would be made to subsidize OER production and use in the long-term, rather than employ the same funds in other equally-worthy public endeavours.

Non-monetary exchange processes have been proposed, whereby reciprocal services such as production, hosting, cataloguing, quality control, and distribution activities could be shared among participating institutions. Other potential cost efficiencies could be realized by limiting aggregation and distribution costs of OERs to fewer institutions, transferring course material from formal learning management systems into lower-cost OERs repositories, forming membership-based consortia to spread development and distribution costs, establishing wikis to inexpensively develop and improve OER material, and using social software to capture suggestions by users for quality improvements (Atkins, *et al.*, 2007*;* de Langen, 2013; Stacey, 2010). However, no successful examples of these approaches have been cited, and it appears that some cash would still be required to implement the proposals.

In total, there appear to be few feasible suggestions in the literature about how OER production and use can result in stable, internally-generated net revenue streams for non-elite institutions. This is rather curious, given the vast amounts of money spent on educational material each year and the potential cost savings for students. For instance, the average American undergraduate spent almost US$1,200 per year on textbooks and other learning resources in 2011 (Butcher and Hoosen, 2012).

One major impediment is the current physical infrastructure needs of higher-education institutions. Most charge tuition to students. On initial examination, an institution could internally reallocate funds to encourage faculty to incorporate OERs, create greater cost-savings for students, and market this competitive advantage. Students would be attracted by lower overall educational costs. Other factors being equal, more students would choose the institution. Enrolments should increase.

The problem is that incentives to increase demand for higher education by lowering costs are not needed in most jurisdictions. Limited supply is the issue. Cost reduction as a means to increase competitive advantage is not a significant motivator because institutions generally do not have the additional space to accommodate increased demand.

There are other impediments. In common with most organizations, higher education institutions seek to not only survive but to grow bigger and better at what they do. The means to do this include more courses and programs, finer buildings, accreditation, and better-qualified faculty. These innovations in turn cause costs to increase (Christensen and Eyring, 2012). As a result, potential innovations like OERs that reduce the costs of education are unlikely to be embraced by existing higher education institutions as they are at odds with this innate tendency of the entire sector to provide increasingly up-scale services.

However, there are contra examples. The following case study illustrates how certain internal financial incentives can create an extensible, self-sustaining revenue model for OER production.

Description of the OER Project

Athabasca University is located in Alberta, Canada. Since its formation in the 1970s as the province's fourth publicly-funded university, its mission has been to reduce barriers that traditionally restrict access to university-level education for adults throughout the world. To accomplish this, the institution has adopted open access policies in its undergraduate courses—for instance, offering courses almost exclusively by online education; admitting any adult regardless of prior education; arranging comprehensive transfer credit arrangements with other educational institutions; and assessing students' prior, non-formal learning experiences for university credit. The University spends a considerable amount of time and financial resources preparing course materials. These are provided to students as part of their course tuition.

The University's Faculty of Business offers an undergraduate introductory financial accounting course. As in most other post-secondary business programs, the course is required and heavily subscribed. It consistently ranks as one of the top three courses at the institution in terms of enrolments. From 1989 to 2000, two editions of a popular commercially-available textbook were used in the course. For several reasons, publication ceased and the copyright reverted to the original author. The author (unable to participate further because of health issues) was approached about the possibility of University faculty and staff revising the text, then publishing it in-house to use in its introductory financial accounting course. The copyright holder agreed to this arrangement and received per-text royalties from the university.

The in-house edition was published by Athabasca University Press in 2000. There was no attempt to make the finished product available as an OER. However, a beneficial by-product of this process was that Athabasca University created and retained the digital files for this edition of the text and solutions manual (approximately 1,400 pages in total). It also obtained the right to distribute this material in any medium to its students.

Printed and e-book versions of this text were used in the introductory financial accounting course from 2000 to 2003. The text was replaced with another (commercial) textbook when a new faculty member took over the course. The digital files of the in-house text were stored on an Athabasca University server for over a decade. During 2012, a second phase commenced. An accounting faculty member at the University began to update the pre-existing digital files to incorporate changes to Canadian financial accounting standards that had occurred in the intervening period. A second author and an editor also reviewed and revised the material. This new version of the text began to be used in the University's introductory financial accounting course starting in 2015. Significantly, the copyright holder agreed that the new version would be licenced under a Creative Commons regime, requiring only attribution to the original authors and production of non-commercial derivatives unless by negotiated agreement (CC-BY-SA-NC).

As a result, and about the same time the new version of the course opened, the OER material was posted to several websites (for instance, see http://open.bccampus.ca/find-open-textbooks/), and made available in.pdf and .docx formats. Print versions of the student solution manual and a student workbook are also available. A free, complete instructor solutions manual in .docx format is available on request. In all, over 1,400 pages of instructional material were developed.

There were several non-financial factors that made this an attractive OER project for the University. It had recently joined the OERu consortium as a charter member (see http://oeru.org/), and now formally supports the development, use, and distribution of OERs as a means to make higher education more affordable. This in turn was informed by the overwhelming number of "no significant difference" results from comparative media studies in the intervening years that suggested better learning outcomes through the use of commercial textbooks were likely minimal or non-existent, and their significantly greater costs therefore unwarranted (see also Wiley, 2014).

However, the primary benefit of and impetus for this particular OER project was financial. As noted earlier, Athabasca University benefits financially from the development and use of OER since the University's tuition fees include the costs of all instructional materials. Using OERs saves the institution significant amounts of money. Projected internal cost-savings had significantly increased over the last decade. From 2003 to 2015, the commercial text used in the financial accounting course had trebled in price to about €145, and yearly enrolments in the course had grown to more than 1,700 students. Over a standard three-year revision cycle, cost savings to the institution now approached €740,000. The incremental cash outlays for the University to produce the OER text were almost zero because of the pre-existing digital files from the first iteration of the project.

These internal costs savings have more than underwritten all incremental production costs of the OER version. Recognizing the potential overall cost savings to the institution, the necessary writing and revising work by faculty members and editors was agreed by administrators to be done as part of their regular duties. These activities are also recognized as valid scholarly and research activities by the institution.

There are still organizational issues that inhibit wider adoption of OERs within the University's several hundred online courses. Its financial situation is tenuous, restricting the ability to invest in up-front resources often required to produce OERs. Some senior decision makers are unsure whether the University should continue to supply learning materials at all to students, requiring them rather to purchase these resources on their own in common with most other higher educational institutions. This creates a drag on larger institutional buy-in. A recent, relatively problematic transition to commercial e-texts in a number of courses and a misguided perception among some faculty that OERs will necessarily create similar issues, has dampened enthusiasm for large-scale adoption of OERs. There are also intra-institutional barriers. Costs of learning materials are charged to a centralized purchasing department. Thus, all savings realized by the use of OERs accrue to this department (and thence the University as a whole) rather than the initiating academic faculties. Yet the various faculties must still provide most of the resources to enable OER production, like faculty and editor time. This creates a financial disincentive within the faculties. Finally, there is criticism that the University is in effect giving away one of its most strategic advantages – high-quality learning material.

Still, the financial savings realized by the described small-scale OER project and the much larger implications for widespread OER adoption within the institution are clear. The University spends about €200 per course registration on learning materials (2014 total: €8.1M). These potential cost savings create internal incentives for management to re-align faculty workloads, and reward the production and use of OERs. Money can be saved, tuition fees can be lowered, and enrolments can be increased without additional government funding, other things being equal.

Of course, the important question is whether similar conditions can be created across many political jurisdictions to promote the development and use of OERs. A simple expedient would be for governments to require that higher education institutions use OERs. However, this could be perceived as an attempt to limit academic freedom and meet with significant resistance from the academy.

There is another relatively straight-forward means to produce a large-scale, system-wide model of self-sustaining OER production and use. The state should require that the cost of all instructional materials be included in tuition fees charged by higher education institutions within its jurisdiction.

Athabasca University is almost unique in that the costs of all instructional materials are included in student tuition fees. The ability of the institution to lower these costs and directly realize financial benefit was the largest determinant of success of the OER project described above. Contrast this with the realities in most other higher education institutions. Allen and Seaman (2014) found that instructors are overwhelmingly responsible for choosing their students' learning materials, but these costs are borne by students at 97% of surveyed institutions. As well, the lower cost of OERs was considered by surveyed faculty to be one of their least important attributes (2.7% of respondents). The data seem to indicate that course professors overwhelmingly choose commercially-produced textbooks because these provide comprehensive coverage, and have high-quality production value, plentiful instructional aids, and good assessment material. All these features reduce the amount of time or effort needed to prepare and teach. Institutions' costs are reduced by choosing commercial texts because more faculty time can be assigned to actual teaching, not developing instructional material. Most higher education institutions also benefit more directly from the use of commercial textbooks. Their bookstores produce significant profits by marking up purchase price. All these factors skew teachers' and administrators' preferences away from OERs. Meanwhile, students literally bear the extra cost of these choices since they must purchase the texts themselves and in additional to their tuition fees. Fundamentally, their financial interests do not align with those of their institutions.

Requiring the costs of instructional materials to be included in tuition fees would provide a powerful incentive for institutions to reduce these costs. Also, and as de Langen (2013) suggested, a sustainable business model for OERs must align overall strategy of an organization with its internal operations. Including instructional costs in tuition fees would encourage individual institutions to re-organize teaching activities and reallocate internal funds towards the investigation, adaptation, and development of OERs. Sclater (2010) suggested needed internal restructuring: changing tenure and promotion criteria, clarifying ownership of OERs, obtaining high levels of commitment from senior managers, developing new models for production and quality assurance, and taking advantage of emerging licensing and distribution regimes. Of particular importance, he argued, was the need to integrate the production of OERs fully into the educational processes of the institution, rather than relying on individual faculty members. This included release time for faculty to evaluate and develop OERs, and adapt their teaching practices accordingly. But this can only occur if appropriate financial incentives are put in place. Requiring tuition fees to include the costs of learning materials would be the first and perhaps most critical step in positively propelling all these needed changes. It would spur internal realignment of currently-conflicting forces that limit OER production and use within most higher education institutions by holding out the promise of reduced institutional costs.

There is one additional requirement for widespread OER adoption. Incentives need to discourage 'free-riders'. Otherwise, a valid competitive strategy for institutions would be to wait and merely use without cost the OER resources produced by others, much like the early and late majority adopters described by the innovation diffusion model of Rogers (2003).

In fact, the solution to this problem has already been instituted in many jurisdictions. In these cases, governments have provided funds for the identification of existing OERs suitable for use in popular post-secondary courses, or for their development. Once relatively comprehensive open educational resources have been developed for a particular course, there is little additional cash outlay needed by a given institution to adapt OERs to its instructional needs. The free rider problem is addressed by providing initial funds for OER development. This lowers and perhaps entirely offsets development costs for early adopters and sufficiently reduces the advantages otherwise realized by free riders. With the now-present capabilities to locate suitable OERs across the planet, the related benefits of start-up funding for OER development can be realized if even a few jurisdictions provide this.

Therefore, it appears that the largest obstacle to widespread OER use is not their scarcity, but their lack of uptake. A mind-set of openness, sharing, and collaboration needs to be cultivated among institutions, administrators, and teachers. Requiring costs of instructional materials to be included in students' tuition fees would provide the needed incentives for this to occur, and promote a virtuous cycle of adaptation, development, and re-sharing within the academy at large.

Conclusion

Many broad-based developments auger well for future OER production and use: a growing awareness that knowledge is a public good; technology that now allows the discovery, sharing and reuse of knowledge on an unprecedented scale; governments increasingly committed to building OER repositories and funding their development, creation of effective open licensing regimes like Creative Commons; and the dearth of institutions able to cost-effectively meet the staggering current and projected demands for post-secondary education worldwide (Atkins *et al.*, 2007).

Yet incentives are still lacking to reduce the costs of post-secondary education and to integrate the financial interests of governments, institutions of higher education, faculty members, and students. These interests could be more closely aligned by simply requiring tuition fees to reflect the costs of learning materials. This would provide a sustainable net revenue stream for the production and use of OERs within individual institution of higher learning, and lead to the gradual replacement of commercially-produced learning material. This in turn would lower overall higher education costs. Production of open educational resources used in an introductory financial accounting course at Athabasca University provides an example of this.

References

Allen, I. & Seaman, J. (2014). *Opening the curriculum: Open educational resources in U.S. higher education, 2014*. Report published by Babson Survey Research Group. Retrieved from http://www.onlinelearningsurvey.com/reports/openingthecurriculum2014.pdf

Armellini, A. & Nie, M. (2013). Open educational practices for curriculum enhancement. *Open Learning, 28*(1), 7–20. Retrieved from http://dx.doi.org/10.1080/02680513.2013.796286

Atkins, D., Brown, J., & Hammond, A. (2007). *A Review of the Open Educational Resources (OER) Movement: Achievement, Challenges, and New Opportunities*. Report to the William and Flora Hewlett Foundation. http://www.hewlett.org/uploads/files/ReviewoftheOERMovement.pdf.

Barrett, B., Grover, V., Janowski T., van Lavierena, H., Ojoa, A. & Schmidta, P. (2009). Challenges in the adoption and use of opencourseware: Experience of the United Nations University. *Open Learning, 24*(1), 31-38. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/02680510802627803#.U7bn1fldU8k

Bates, A "*The cost of developing an open textbook: $80,000 - $130,000*." June 8, 2015. Retrieved from http://www.tonybates.ca/2015/06/08/the-cost-of-developing-an-open-texbook-80000-130000/#sthash.uB2f5MLI.Q0whLkxq.dpuf

Bossu, C. & Tynan, B. (2011). OERs: new media on the learning landscape. *On the Horizon*, *19*(4), 259-267. Retrieved from http://www.emeraldinsight.com/journals.htm?articleid=1953822

Butcher, N. (2015) *A Basic Guide to Open Educational Resources (OER).* Commonwealth of Learning, Vancouver. http://unesdoc.unesco.org/images/0021/002158/215804e.pdf

Butcher, N. & Hoosen, S. (2012). *Exploring the business case for open educational resources*. Commonwealth of Learning. Retrieved from http://www.col.org/resources/publications/Pages/detail.aspx?PID=421.

CERI (2007) Giving knowledge for free: The emergence of open educational resources. Center for Educational Research and Innovation. http://www.oecd.org/edu/ceri/38654317.pdf.

Christensen, C. & Eyring, H., (2012). The innovative university: Changing the DNA of higher education. *Forum for the Future of Higher Education,* Educause. Retrieved from https://net.educause.edu/ir/library/pdf/ff1207s.pdf.

Daniel J., & Uvalić-Trumbić, S. (2011). *UNESCO-COL Guidelines for open educational resources (OER) in higher education.* Retrieved from http://oerworkshop.weebly.com/guidelines-for-oer-in-higher-education.html

de Langen, F. (2013). Strategies for sustainable business models for open educational resources. *International Review of Research in Open and Distance Learning*, *14*(2). Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/1533/2485.

de Langen, F. (2012). There is no business model for open educational resources: A business model approach. *Open Learning, 26*(3), 209-222. Retrieved from http://www.tandfonline.com/doi/abs/10.1080/02680513.2011.611683#.U7bX0vldU8k.

Dholakia, U., King, W., & Baraniuk, R. (2006). *What makes an open education program sustainable? The case of connexions.* Connexions cns.org. Retrieved from https://oerknowledgecloud.org/sites/oerknowledgecloud.org/files/36781781.pdf.

Downes, S. (2007). Models for sustainable open educational resources. *Interdisciplinary Journal of Knowledge and Learning Objects, 3*, 29-44. February 27, 2007. NRC *50353.* Retrieved from file:///C:/Users/Public.08D011/Downloads/5764249.pdf

Friesen, N. (2009). Open educational resources: New possibilities for change and sustainability. *International Review of Research in Open and Distance Education, 10*(5). Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/664

Gourley, B. & Lane, A. (2009). Re-invigorating openness at The Open University: The role of open educational resources*.* *Open Learning 24*(1), 57-65. Retrieved from http://www.tandfonline.com/doi/full/10.1080/02680510802627845#.U7WgLfldU8k

Okonkwo, C. (2012). A needs assessment of ODL educators to determine their effective use of open educational resources. *International Review of Research in Open and Distance Learning, 13*(4). Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/1316

Plotkin, H. (2010). *Free to learn: An open educational resources policy development guidebook for community college governance officials.* San Francisco: Creative Commons. Retrieved from https://wiki.creativecommons.org/images/6/67/FreetoLearnGuide.pdf

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: Free Press.

Sclater, N. (2010). The organizational impact of open educational resources. In U.-D. Ehlers & D. Schneckenberg, (Eds), *Changing Cultures in Higher Education: Moving Ahead to Future Learning*, pp. 485-497. Berlin: Springer-Verlag GmbH

Stacey, P. (2010). Foundation funded OER vs. tax payer funded OER – A tale of two mandates. *Open Ed Conference 2010 Proceedings*, Universitat Oberta de Catalunya. Retrieved from http://openaccess.uoc.edu/webapps/o2/handle/10609/5241

UNESCO. (2012). *2012 Paris OER Declaration*. Retrieved from http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/CI/CI/pdf/Events/English_Paris_OER_Declaration.pdf.

Wiley, D. "*A response to 'OER and the future of publishing'*." August 18, 2014. Retrieved from http://opencontent.org/blog/archives/3462.

Wiley, D. & Gurrell, S. (2009). A decade of development. *Open Learning, 24*(1), 11-21. Retrieved from http://www.tandfonline.com/doi/full/10.1080/02680510802627746#.U7R6R_ldU8k

Chapter 11
A Happy Marriage: Academia, Professional and Scientific Associations

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Abstract: This paper advocates for a greater integration between Higher Education and Professional and Scientific Associations (PSAs). With the development and adoption of Information and Communication Technologies (ICTs), the costs associated with the collection, storage, processing, and transmission of information have been reduced. Eventually, the supply of information has soared. However, more does not necessarily imply better. Free online resources can enhance the learning process, but the lack of quality controls is still a major concern. Additionally, learning demands some degree of organisation and structure. We argue that Higher Education can potentially benefit from a closer relationship with PSAs. In doing so, we introduce the Spanish Association of Economic History efforts to organise and prepare high-quality teaching resources. Our brief discussion could provide a route-map for other PSAs.

Keywords: Online resources; Professional associations; Higher Education

Introduction

On September 15, 2008, a well-established investment bank, Lehman Brothers, filed for bankruptcy. Although the financial crisis had already begun, the sudden collapse of the fifth largest investment bank in the world was an *eye-opener* to many people. The unexpected was occurring, and few had foreseen it. However, the 2008 financial crisis opened up new opportunities. As Barry Eichengreen put it in the 2011 Presidential address to the Annual Meeting of the Economic History Association: “This has been a good crisis for economic history…. Journalists, market participants, and policy makers all turned to history for guidance on how to react to this skein of otherwise unfathomable events” (Eichengreen, 2011). A year earlier, Vicky Price, then Joint Head of the Government Economic Service (GES), had argued that, “for the economist, history remains the laboratory through which we are best able to seek to understand how different policies might impact on economic performance. The recent global financial crisis in particular has reminded us how analysis of past periods of economic history can be invaluable in informing contemporary policy questions” (in Crafts *et al.*, 2010).

Although economics had "missed the boat in 2008", as Carlin (2013) said, the general public demanded an explanation, and a subsequent plan of action. What caused the 2008 financial crisis? What could be done to prevent it? What was to be done? More notably, the study of economic history gained momentum or simply, the *demand* for economic history increased. For example, a group of economists launched the CORE project (URL: http://core-econ.org/) to promote a new curriculum in economics where economic history plays a central role. Barry Eichengreen, a distinguished economic historian, became a media mogul in the United States. More than a few journalists, policy-makers, professional and academic economists, students and enthusiasts, are looking at the past to better understand the present (O'Rourke 2013).

Using the Google Ngram Viewer tool, it can be shown how topics, such as "*financial crisis*" and "globalisation" evolved over time. The Google Ngram Viewer provides frequencies of simple words or short sentences in printed resources (i.e. books) available online. Figure 1 can be matched to Kindleberger and Aliber (2005) words: "*the production of books on financial crises is counter-cyclical*".

Figure 1. Frequency of "financial crisis" in printed resources available online, 1812-2008

During the nineteenth century there were several relevant episodes of financial distress in Europe such as the Panic of 1857 in the United States; the 1866 crisis, stirred by the failure of the Overend and Gurney Co. in London; the collapse of the German and Austrian stock market in 1873; or the Baring crisis in 1890. Figure 1 illustrates how all these events stimulated the publication of books and journals with "*financial crisis*". In the twentieth century, the Great Depression of the 1930s marked a turning point. Interestingly, the expression "financial crisis" lost momentum in the aftermath of World War II, possibly due to the financial stability, which came from a stronger regulation of domestic and international markets (Bordo *et al.* 2001). In the last three decades of the twentieth century, financial markets were rather tumultuous as a result of the oil crisis in the 1970s; the Spanish banking crisis in 1976-82; the Latin American debt crisis in the 1980s; and the boom in the real state and stock market in the 1980s in Japan, among others. However, all these events were not reflected in the literature, as figure 1 shows. In fact, we have to wait until the dot.com bubble in the late 1990s for another peak on "*financial crises*".

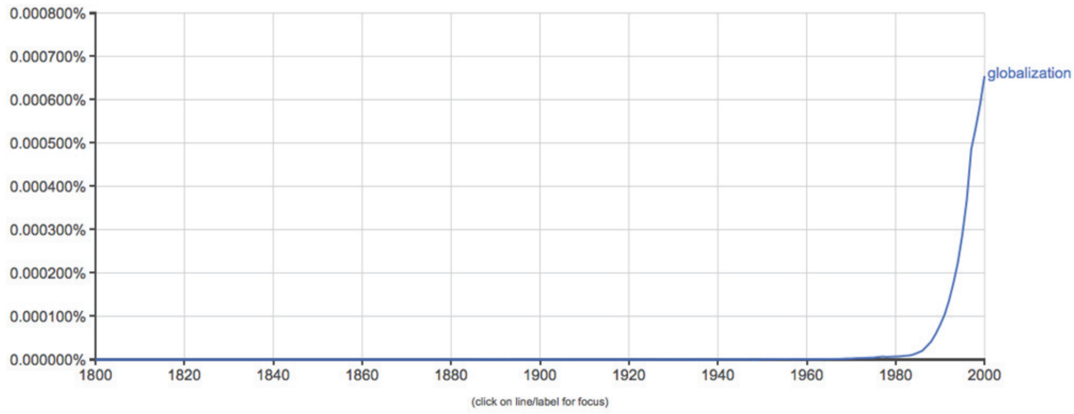

Figure 2. Frequency of "globalisation" in printed resources available online, 1812-2008

There are plenty of examples about the changing nature of the *demand*. Figure 2 captures the long run evolution of the term "*globalisation*". This was virtually unused in the past, but it is central today. According to the Oxford Dictionary, "*globalisation*" was first used in the 1930s, but as Figure 2 displays, it was not part of the literature until the 1980s. Now, "globalisation" is everywhere, television, radio, newspapers, and also, University courses. The Faculty of Economics at the Universitat de Valencia offers a course on *Globalisation and Geopolitics*, as an integral part of a bachelor degree in International Business. Therefore, the changing nature of the *demand* has opened up opportunities or market niches. Whether *supply* and how *supply* responds thus becomes a crucial issue.

Also, with the third millennium came the development and diffusion of Information and Communication Technologies (ICTs). By ICTs, we simply refer to Internet, PCs and laptops, mobile phones and tablets, and software packages capable of collecting, storing, processing, transmitting and presenting information. Clearly, ICTs have greatly reduced the costs associated with accessing information, which eventually opened up new opportunities in education.

Figure 3. ICTs and the supply of knowledge

Figure 3 illustrates the opportunities that an individual enjoys in a context before/after ICTs. Before ICTs, knowledge was mainly transmitted to the general public through university degrees and/or courses organised by either academics or professionals. Additionally, books and academic journals were the main resources. ICTs have thus facilitated a greater *supply* of information. Online resources (academic and non-academic articles; blogs, courses, websites) provide a wider range of tools in the learning process, and in most cases are free. But, how reliable are these? More quantity does not necessarily imply high quality. In fact, the lack of quality controls appears to be a major concern. Moreover, the learning process requires structure and organisation. For this, several institutions have launched Massive Open Online Courses (MOOCs). MOOCs are usually open-access courses with a proper structure, and materials such as lecture notes, reading lists, and problem sets. Additionally, MOOCs provide students with the opportunity to regularly interact with lecturers or teaching assistants. Therefore, online courses have quality control mechanisms and a basic structure. However, the completion rates hardly reach 20% (Jordan, 2013).

Besides, the European Science Foundation (ESF) published a paper in 2013 entitled 'The Professionalization of Academics as Teachers in Higher Education', in which it noted that "the purpose of educational development…is to help create learning environments that enhance educational quality…In this way, old teaching methods that focus on teachers' rather than students' needs and on the subject matter rather than on the transformation of student knowledge perpetuate from generation to generation. In addition to the questionable effectiveness of such methods, lack of teacher preparation runs counter to political rhetoric, as well as current trends in and expectations on higher education". Conventionally, teachers acted as senders whereas students as receivers. However this system could eventually fade away. ICTs have not just expanded the supply information, but have radically transformed the learning process. Similarly, the European Union (EU) policy established an Education and Training 2020 (ET 2020) framework in 2009 with four main goals, summarised as follows: (i) Lifelong learning and mobility; (ii) Quality and efficiency of education and training; (iii) Equity, social cohesion, and active citizenship; (iv) Creativity and innovation, also entrepreneurship. Under these circumstances, ICTs become a key tool in the learning process.

Certainly, University degrees and short courses provide quality controls and structure, but what if the expertise does not entirely match with the *demand?* Suppose there is not much expertise on the "*history of financial crises*" in any given Faculty or Department of Economics. Bearing this in mind, there are some alternatives. First, do nothing, thus the *demand* remains unmatched. The *supply* does not respond to the preferences of prospective students. Second, the expertise could be recruited via job openings. Ideally, this is a first-best, but budgetary restrictions and/or non-monetary barriers to hire personnel may prevent this from happening. Third, if hiring is not viable, those faculty members responsible for organising the course will incur into an extra cost, unless guidance and reliable materials were available. Then, how could we cope with the changing nature of the *demand?*

We propose an approach to balance *demand* and *supply* within the traditional context of university degrees. Generally speaking, we argue that Professional and Scientific Associations (PSAs), namely learned societies, should play a greater role in Higher Education. Nowadays, Primary and Secondary Education could benefit from PSAs, e.g. online platforms. However, this is not the case for Higher Education, particularly in Social Sciences and Humanities.

Professional and Scientific Associations (PSAs)

Professional and Scientific Associations, henceforth PSAs, were created to promote and support excellence in a particular discipline. For example, the Royal Society, founded in the second half of the 1600s, was aimed at encouraging "*the development and use of science for the benefit of humanity*". In Spain, the Royal Academy of History was granted a charter in 1738. The National Academy of Sciences (NAS) was founded in the United States on March 3, 1863. PSAs eventually grew in size, and became essential in the difficult task of the transmission of knowledge through conferences, workshops and journals. The Royal Society published the first issue of the Philosophical Transactions in 1665. Table 1 illustrates a short-list of PSAs, with a special emphasis on Economic History, by country, and year of foundation.

Table 1. PSAs by country and year of foundation

PSA	Country	Year of Foundation
Royal Society	United Kingdom	1660
Académie des Sciences	France	1665
Real Academia de Ciencias	Spain	1834/47
National Academy of Sciences	United States	1863
American Economic Association	United States	1885
Economic History Society	United Kingdom	1926
Economic History Association	United States	1940
International Economic History Association	World	1960
Association Française d'Histoire Économique	France	1965
Economic and Social History Society of Ireland	Ireland	1970
Asociacion Española de Historia Economica	Spain	1972
History of Economics Society	United Kingdom	1974
Associaçao Portuguesa de História Económica e Social	Portugal	1980
Cliometric Society	United States	1983
European Historical Economic Society	Europe	1991
Association Française du Cliométrie	France	2001

Notwithstanding PSAs have played a crucial role in the dissemination of frontier knowledge and values (Price 1980; Yungmeyer 1983; Matthews 2012). But modern times call for further action. The *Royal Society* has created an online platform "Education & Skills" for Primary and Secondary Education. The *American Economic Association (AEA)* provides online resources, while the *Economic History Association (EHA)* has a website with articles and other materials prepared by a broad team of experts. In particular, the EH.Net Encyclopaedia of Economic and Business History provides high quality reference articles in the field of economic and business history; these articles are written by experts and peer-reviewed. In the United Kingdom, the *Economic History Society (EHS)* also provides online resources, e.g. podcasts, videos. Interestingly, the Bank of England and the Federal Reserve Bank of St. Louis offer a great amount of educational resources too. Then, what role should PSAs play in Higher Education? Should PSAs be responsible for quality control?

Having said that, we advocate for a greater integration between Higher Education and PSAs. We believe that PSAs could coordinate efforts across researchers and practitioners. In fact, they could bridge the gap between frontier research and Higher Education. High quality teaching materials can be produced and disseminated. Recent developments can be easily incorporated, thereby linking frontier research and teaching. To motivate our claim, we first introduce our experience at the Universitat de València. Then, we present the Spanish Association of Economic History case.

Economic History at the Universitat de València

The *Área de Historia e Instituciones Económicas* at the Universitat de València has always made a great effort to promote the study of economic history. In 2010-11, the Facultad de Economía established several new degrees: Business Administration (GADE); Economics (GECO); Finance and Accounting (GFYC) and International Business (GIB). The *Área de Historia e Instituciones Económicas* or the Economic History Group (EH-Valencia) is in charge first-year courses such as World Economic History and Spanish Economic History (GECO), World Economic and Business History in (GADE; GFYC), and Geopolitics and Globalisation (GIB). Moreover, EH-Valencia also runs optional four-year courses.

Figure 4. EH-Valencia Facebook

In 2014, EH-Valencia published a world economic history book, which was accompanied by online teaching materials (Palafox, 2014). Our initial aim was to *supply* students with a well-structured, easy-to-read, and up-to-date book, in which new topics were incorporated. Moreover, our economic history courses show students how economic analysis allows us to better understand the past. Furthermore, EH-Valencia has also launched an online platform (website; blog; facebook; twitter), as figure 4 shows. Our objectives were threefold: (i) To encourage the study of economic history; (ii) To introduce students into major topics and debates; (iii) To promote students' abilities in terms of analysis and discussion. For example, within the EH-Valencia Facebook and Twitter accounts, students can easily find online resources (web links) related to the main topics explained in the lectures. This has encouraged the interaction between students and lecturers in class. Although our experience with ICTs, particularly social networks, is reassuring, we still face several challenges. One of them, once again, is how to deal with the changing nature of the *demand*.

In recent decades, "financial crises" and "globalisation" have become central in economic history research and teaching. At the Universitat de València we have made great efforts to increase their presence in two courses: World Economic and Business History, and Geopolitics and Globalisation. In fact, the latter one was first introduced in 2011 as a first-year compulsory module of a brand-new bachelor degree in International Business. Besides, following the directives of the European Union, we have also attempted to change the learning experience. In doing so, we promote lifelong learning and creativity with a mixture of lectures and practical classes. All in all, our expertise is limited in certain topics, and we acknowledge this. Job openings and/or promotions have been curtailed since 2011. Therefore, we have made an effort to update/upgrade our knowledge. In doing so, we have benefitted from the Spanish Association of Economic History online platform.

There are other platforms within economic history in Spain. Our colleague at the Universidad Pablo de Olavide (UPO), Fernando Ramos Palencia, launched a Blog on *Historia Económica, Globalización y Desarrollo/Economic History, Globalisation and development*, with numerous entries and a great bunch of teaching resources. There are other blogs, but mostly research-oriented, e.g. Juan Flores (University of Geneve) with other colleagues launched a blog on "*Past and Present of the World economy*". Personal web pages are also another source of knowledge. In these, authors provide their personal opinions and materials, which are selected according to the courses taught or their research expertise. Table 2 summarises the online opportunities available. All in all, the supply of information exceeds the capacity that an individual or a group of teachers have to evaluate and organise.

Table 2. Online resources by type, purpose and *main client*

	Personal and Departmental websites	PSAs websites
Main purpose	Research &Teaching	Research &Teaching
Main client	Academics Students	Academics

Therefore, PSAs could provide greater uniformity and homogeneity. Moreover, by selecting and classifying educational online resources, PSAs could guarantee a high-quality standard. Even more, PSAs could create a discussion forum for teaching and educational purposes. In this line of thinking, we would like to present and discuss the active role played by the *Asociación Española de Historia Económica (AEHE)* in the development of online teaching materials. Although this is a just a simple case, it can easily illustrate how PSAs could participate more actively in Higher Education.

The Spanish Association of Economic History

The Spanish Association of Economic History or *Asociación Española de Historia Económica* (AEHE) was founded in 1972. Since then, it has promoted research and teaching related to economic history. The AEHE organises a national congress every three-four years to encourage the exchange of frontier research in economic history. The last one was held in Madrid on September 4-5, 2014. In 2005, the academic journal *Investigaciones de Historia Económica* was launched too. In addition, several initiatives have recently been introduced to promote excellence in teaching and research. One of these was the organisation of Teaching Workshops or *Encuentros de Didáctica de la Historia Económica*. The first meeting was organised in 1990 at the Universidad de Zaragoza, while the last one was held in Santiago de Compostela in 2014. These periodical meetings have allowed academics to interact and share their views and/or problems on the teaching of Economic History in Higher Education. It was in one of these workshops where the idea of creating an online platform came up.

The AEHE shortly answered to the demands of its members, and the *Sección de Docencia* or Teaching Section (URL: http://www.aehe.net/docencia.html) was created. This portal is free, and is currently organised by Elena Catalán Martínez (Universidad del País Vasco) and Miguel Ángel Bringas (Universidad de Cantabria). Pablo Gutiérrez González (Universidad de Sevilla) and Alfonso Díez Minguela (Universitat de València) have also collaborated.

The Teaching Section has four main goals: (a) To provide further information about the discipline of economic history across Spanish universities (i.e. syllabus); (b) To supply educational and teaching resources related to the discipline; (c) To encourage the use of novel teaching methodologies; (d) To encourage discussion forums among lecturers. Figure 5 shows the main organisation of the Teaching Section. First, *GUÍAS DOCENTES* include the available course syllabus across Spanish universities by region, whereas *MANUALES* provides information on the main textbooks by subject. The front cover and index of these textbooks have been scanned and uploaded as guidance for prospective teachers. *CURSOS EN ABIERTO* and *MATERIAL AUDIOVISUAL* is a collection of online courses, videos, films, and pictures related to economic history. MOOCs have also been included in the former one.

One of the most interesting is *PRACTICUM*, where several teachers have prepared online materials for a specific topic. All these have been properly peer-reviewed by an Advisory Board, which acts as a quality control mechanism. Furthermore, teachers are also researchers, and these materials are closely related to their interests. This is an example of how a greater integration between Higher Education and PSAs could potentially benefit Higher Education. Moreover, biographies, databases, maps and list of teaching tools can be found in *RECURSOS DIDACTICOS*. *ENCUENTROS DE DIDACTICA* and *REVISTAS DE DOCENCIA* mainly refer to the series of events organised by the Spanish Association of Economic History to promote the teaching of economic history, and a list of journal on Higher Education in social science. Press articles, special issues, blogs and websites of interest are organised in *ACTUALIDAD INFORMATIVA*. Finally, the Spanish Association of Economic History also awards a prize, *PREMIO DOCENTIA*, to individuals or groups for their outstanding contribution to the teaching in economic history.

Figure 5. The *Teaching Section*, Spanish Association of Economic History

There is little doubt that this Teaching Section has had a tremendous impact within the discipline. But, amassing and organising all these resources is costly. Each voluntary contribution needs to be reviewed, thus a committee has been created. Free riding is another major limitation. Although the AEHE has managed to achieve a good deal of participation, coordinating reviewers and encouraging new entries has required a great commitment by the organisers. Finally, to maintain and update online resources is costly. This, in turn, is one of the main problems of the Teaching Section. Whether or not funds will be available to carry on will depend upon its financial capacity. This, in turn, has relevance in our discussion. On the one hand, free riding and shirking are major challenges that need to be overcome. Currently, the AEHE is paying 60 euros for biographies of business people. To our knowledge, this is generating positive but inadequate incentives. The clash between private and social returns can be easily seen in this context.

Despite of the limitations, we believe that the Spanish Association of Economic History provides evidence that PSAs could be the way forward. Since PSAs have as ultimate goal to promote and support excellence in a given discipline, and the vast amount of available information exceeds the capacity of an individual or small group, PSAs could play a role of intermediation and bring up-to-date frontier research to the class.

Conclusions

With the development and adoption of Information and Communication Technologies (ICTs), the costs associated with the collection, storage, processing and transmission of information have been reduced. Eventually, the supply of information has boomed. These online resources provide a wider range of tools in the learning process, but more does not imply better. For this reason, we advocate for a greater integration of Higher Education and Professional and Scientific Associations (PSAs). With ICTs, several PSAs have greatly increased curriculum-linked online materials, but mostly for primary and secondary education. For example, the Royal Society in the United Kingdom organizes Summer Science Exhibitions and provides teaching resources in its recently developed website: Invigorate. Why not marrying Academia with PSAs to enhance teaching in Higher Education? Teaching materials could be reviewed, organised and structured. To further support our claim, we introduce the Spanish Association of Economic History effort to promote the teaching of economic history. Although the Teaching Section can be greatly improved, we regard it as first step in the right direction. ICTs can greatly enhance the learning process, but teachers alone cannot cope with the vast amount of available information. The greater degree of specialisation could potentially increase the gap between frontier research and the classroom. PSAs are a potential solution, as we have discussed above.

References

Bordo, M., Eichengreen, B., Klingebiel, D., & Martinez-Peria, M. S. (2001). Financial crisis. Lessons from the past 120 years. Is the crisis problem growing more severe? *Economic Policy*, April, 53-82.

Carlin, W. (2013). Economics explains our world -but economics degrees don't, *The Financial Times*, November 17, 2013.
URL: http://core-econ.org/wendy-carlin-in-the-ft-teaching-what-matters-in-economics/

Crafts, N.G, Bakker G., Michie R, Leuning T, Tennet N, Owen N & Hartley, K. (2010). Learning from some Britain's successful sector: a historical analysis of the role of government. *BIS Economic Papers* 6.

Eichengreen, B. (2011). Economic History and Economic Policy, *Presidential address to the Annual Meeting of the Economic History Association*, Boston, MA, September 2011 .
URL: http://eml.berkeley.edu/~eichengr/EHA_Pres_Add_9-9-11.pdf

European Science Foundation (2013). *The Professionalization of Academics as Teachers in Higher Education.* Science Position paper.

Official Journal of the European Union (2009). *Education and Training 2020.* May 12, 2009

Jordan, K. (2013). MOOC Completion Rates: The Data.
URL: http://www.katyjordan.com/MOOCproject.html

Kindleberger, C. & R. Z. Aliber (2005). *Manias, Panics, and Crashes: A History of Financial Crises*, New Jersey: John Wiley & Sons.

Matthews, J. (2012). Role of Professional Organizations in Advocating for the Nursing Profession. *The Online Journal of Issues in Nursing*, 21

Price, D. A. (1980), The role of Professional Association. *The Canadian Veterinary Journal*, 21 (2), 33-38.

O'Rourke, K. (2013). Why economics needs economic history. *VOX.* July 24, 2013.

URL: http://www.voxeu.org/article/why-economics-needs-economic-history

Palafox, J. (ed.) (2014). *Los Tiempos Cambian: Historia de la Economía*, Valencia: Tirant Humanidades.

Yungmeyer, E. (1983). The Role of Professional Associations in Achieving Excellence. *Journal of Education for Librarianship*, 23 (4), 264-272.

PART IV

Innovative Teaching Methods

Chapter 12

Teaching/learning methodologies based on microprojects and internationalization to increase students' motivation on technical subjects

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Abstract: This paper describes the full implementation of an educational methodology based on microprojects in the subject 'Manufacturing Technology'. This technical subject is given in three engineering degrees under the EHEA (European Space of Higher Education) framework. The main idea is the consolidation of the theoretical background information using different microprojects requested by foreign entities. Students must implement the knowledge acquired in classroom studies facing real-world problems such as definition of scope, planning and team work. At the same time, this project promotes the use of English as well as Information and Communication Technologies (ICTs). In addition, a communication network between the university and international entities is enhanced and students have the opportunity to look closely at different professional environments. Our proposal also provides students a broad view of current state of manufacturing technologies with a strong focus on promising additive manufacturing technologies. Results obtained demonstrate that students had higher motivation and greater level of interest after implementation than in previous years. They clearly enhanced their final scores in comparison with other courses where traditional teaching/learning methods were implemented.

Keywords: Microproject; PBL; English; Engineering; Manufacturing Technology

Introduction

The European Space of Higher Education (EHEA) promotes new educational models that focus on students' autonomous workload and other learning activities, some of them based on project based learning (PBL) methodologies (Buck Institute for Education, 2002). Besides this, a growing demand for professionals with greater leadership skills, accentuated internationalisation profile, and enhanced adaptation capabilities for changing environments boosts the updating of traditional teaching methods to meet current companies' requirements.

Traditional teaching methods rarely promote interactions neither among students nor between teachers and students. So, students become passive characters who may be overwhelmed sometimes by the quantity of theoretical contents of the subjects. As pointed out by Han *et al.* (2015) among others, these methods never encourage students' interest and do not facilitate the development of critical thinking and problem solving skills in them. Consequently, students find serious difficulties to apply the theoretical concepts in real-world problems when they enter into the working world. Indeed, this is a particularly dramatic step on students' life, whose role must turn into an active attitude.

Students have to show many personal skills, such as leadership, communication capacity, integration in multidisciplinary groups, problem solving capacity and, last but not least, mastering English as a universal language within the engineering circle. For that reason, it is necessary to introduce changes in our traditional teaching methods that enhance the students' personal work, the interrelationships among people in the company, the use of a second language, and the use of Information and Communication Technologies (ICTs).

The PBL model, which is widely spread in technical studies, includes some of the aforementioned points (Gary, 2015); in particular, it promotes students' active work throughout the planning, development and final evaluation of different projects with real-world applications beyond educational purposes (Marti *et al.*, 2010). Several experiences have been reported up to date in this field (Garcia-Almiñana & Amante, 2006; Labra *et al.*, 2006; Aliane & Bemposta, 2008; Villalba *et al.*, 2009) and all of them reveal multiple advantages: PBL fosters cooperation and creativity, stimulates autonomous learning and provides learnings on a higher cognitive level.

The methodology proposed is based on microprojects requested by foreign entities. This methodology has been implemented on the technical subject 'Manufacturing Technology', offered in three engineering degrees at the University of La Rioja: *Mechanical Engineering*, *Electrical Engineering* and *Industrial Electronic and Automation Engineering*. Through this methodology, students implement the knowledge acquired in classroom facing real-world problems such as definition of scope, planning and team work. At the same time, they become familiar with the use of English and ICTs. A similar methodology can be found in (Gilbert *et al.*, 2015) where community-engaged projects were presented to engineering students in developed countries. These international projects demonstrated to be highly motivating for students. Moreover, Heikkinen and Isomotten (2015) improved the learning mechanism in engineering courses using what they called 'multidisciplinary working life project' for real customers. Nguyen and Siegel (2015), also proved how PBL applied to real world problems can benefit students' learning in technical courses.

This methodology has been implemented through the 'Teaching Innovative Project' presented during two consecutive academic years: 2013/2014 (Fernandez-Ceniceros *et al.*, 2014) and 2014/2015, adding some upgrades in the last year. Along these two courses the methodology has demonstrated substantial improvements in the teaching methods. Students' motivation for this subject increased significantly during this period. Moreover, their average scores and success rates raised significantly when comparing them to other traditional teaching methods used during previous years 2007/2008 and 2009/2010.

Objectives

The general objective of the methodology proposed is to foster undergraduate students' motivation when learning a specific applied subject such as 'Manufacturing Technology'. It is crucial for their training to acquire information about industry. This can be done through the contact with several companies, research centres and universities. In this regard, students can assimilate the theoretical concepts presented in the classroom in an improved way. Moreover, in a globalized world, it is very motivating to collaborate with international entities/companies, promoting the use of the English as a second language and pointing out the barriers and difficulties of a different culture and working habits, at the same time that promotes the use of ICTs as an interchange platform among the involved agents.

The specific objectives are the following:

- To establish communication networks between University of La Rioja and other international entities from both the teaching and the industrial world. The goal of this relationship is to bring the professional environment closer to the students. To this end, we presented a 'microprojects' framework in which foreign institutions act as petitioners.
- To promote the use of a second language. In this case, the use of English, as the main universal scientific language is promoted. The aim is that students overcome the perception of English as a barrier to learn and interact (Young, 2014). As stated in Nunan (1989), student's attention must be focused on meaning rather than on the linguistic structure, and PBL is an excellent environment for that to happen. This is addressed through the use of English in scientific articles and multimedia content to develop issues related to the manufacturing processes that lie under the microprojects. Moreover, English is used as the communication way between the foreign collaborators and the students. The petitioner establishes the tasks to be developed also in English. Previously, students are provided with all the information translated into its mother language and also a glossary including the most important terminology of the subject. It should be highlighted that our aim is not to implement English as the main language in this subject, but to familiarise the students with the key concepts presented in English due to its great importance for his future working life.
- To increase the access to ICTs through the use of new communication and teleworking environments. Relating microprojects to foreign entities represents a great opportunity to make use of different ICTs resources such as: a web environment to exchange information between petitioners/professors and students, videoconference and digital blackboard to state projects scope and objectives between the involved parts.
- To provide students a state-of-the-art about the current manufacturing technologies. The collaboration with technologically advanced institutions brings new manufacturing techniques closer to students. One of these new techniques is the additive manufacturing, implemented in 3D printers. Along one of the microprojects, students have to learn how to use these printers to make 3D prototypes and elaborate tangible pieces. Besides, following the open-source-RepRap-philosophy (http://reprap.org), students can contribute with ideas that improve designs, materials and software. Finally, they can put into practice the contents learned in the subject. The most innovative designs can be manufactured in the available 3D printer.

- To improve educational techniques by conducting seminars given by experts from industry or other institutions to provide another professional point of view of the concepts applied in the microprojects. In addition, and with the aim of improving the continuous evaluation, guided discussions and small tests are performed after the mentioned seminars, promoting students' participation. Another aim is to improve educational assessment by providing students with an evaluation sheet for each microproject. In this sense students know precisely what will be evaluated and how assessment will be carried out.
- To track the experience and evaluate how students' motivation evolves along the course and how the execution of the microprojects influences on that. To this end, several anonymous questionnaires are addressed. In addition, different written tests after ending the microprojects are carried out to evaluate how these practical experiences help to acquire theoretical knowledge.

Methods

The methodology is based on PBL model and problem solving of cases of study from real-world. It is complemented with seminars and presentations by experts in the three areas selected for the microprojects. The methodology is detailed as follows:

- Theoretical classes to address basic knowledge along with resolution of real-world cases related to the topic of each particular microproject.
- Microproject presentations.
- Seminars given by an expert on a specific area related to the same topic.
- Short tests about basic concepts that will be developed further.
- A platform to integrate everyone involved in the microproject, which is also useful to exchange information (text, glossaries, videos, etc.). This platform will be based on Moodle (http://moodle.org/, Rivas, 2006), an educational resource management platform, which also allows groups to have a forum to discuss about different topics and questions.
- An evaluation sheet to assess the microprojects that will be given to students. In this regard, the methodology evaluates not only the knowledge applied in solving technical issues but also the quality and clarity in the reports as well. This last aspect will be used to evaluate the degree of cooperation of each member in the groups (by a survey to the other group members).
- Workgroups are created with 4 students per group (this number is related to the total of students in the classroom, which is usually around 60). Each group's member must sign a document named 'Group Constitution Agreement'. This is mandatory since through this document students commit themselves to finalise the assigned tasks on time. It also incorporates the concept of 'expulsion rules'. A draft of the 'Group Constitution Agreement' is depicted in Figure 4**¡Error! No se encuentra el origen de la referencia.**. Since three degrees (Electrical, Electronic and Mechanical Engineering) are involved, the groups will be created as much multidisciplinary as possible, as recommended by Heikkinen & Isomöttönen (2015).

- The international entity (along with the Innovation Group) defines the objectives, tasks, time and costs. This is done through a video and documents in English, which are found in *Moodle*. Reports can be written in Spanish or in English, according to students' preferences.
- Each group distributes their tasks among the group members and establishes the deadlines. The Innovation Group coaches this assignment. Besides, each group will name a coordinator, which will be in charge of supervising the activities and organising meetings to put in common the works and solve doubts. The coordinator will be the link between the group and the members of the Innovation Group.
- Problems stated in microprojects are solved according to the distribution of abovementioned tasks. Therefore, everyone should understand the particular problem studied, search for useful information and make hypotheses in order to solve the problems.
- Clarification of doubts through forums or tutoring with the members of the Innovation Group. Professors have to supervise work on a systematic and periodic basis.
- Workgroups report the solutions for the problems outlined in the microproject, paying attention to the evaluation sheet previously presented.
- The members of the Innovation Group proceed to the final evaluation of the microproject by using the same evaluation sheet aforementioned.
- Surveys are carried out along the course to track the evolution of the students and also to elaborate some statistics about the performance and work satisfaction. Partial results are taken into account for the next microproject. At the end of the experience, a final report is prepared with the complete statistical analysis of the results obtained.

GROUP CONSTITUTION AGREEMENT. GROUP Nº

In ________ (city), ___/___ / 2015 (date), the following students gathered here today:

FULL NAME	*e-mail*	*SIGNATURE*

Students of the subject Manufacturing Technology of University of La Rioja,

AGREE:

• That the appointed Group Coordinator is (posts could be rotational)

Mr (Mrs)...

• That the Group Secretary is (posts could be rotational)

Mr (Mrs)..

AND STATE THAT:

- They are committed to contribute with their best effort and dedication to the achievement of the assigned tasks during the course.
- They are committed to achieve those tasks in mutual satisfaction of all members, and into deadlines.
- Group Coordinator and Secretary could be rotational posts, depending on the tasks assigned and members' skills.
- While performing such tasks, members are required to meet regularly at least once a week for an average period of two hours.
- All members will be on time for the meetings.
- The expulsion rules of a member will be the follows:
  - If a member does not attend to the 60% of the meetings could be expulsed.
  - ____
  - ____
  - ____

Figure 4. Draft of the 'Group Constitution Agreement' signed by students in each assignment

Implementation in the subject 'Manufacturing Technology'

The methodology previously explained was implemented in the subject 'Manufacturing Technology', which is studied in the second year of the engineering degrees. It is offered in three engineering degrees at the University of La Rioja: *Mechanical Engineering*, *Electrical Engineering* and *Industrial Electronic and Automation Engineering*. The professors of the Innovation Group involved in this project belong to the Department of Mechanical Engineering and, more precisely, to the areas of *Manufacturing Processes* and *Project Management*. Moreover, the project takes advantage of the post-doctoral period of one of the members of the Innovation Group that works for the *Division of Pharmaceutical Biosciences* (University of Helsinki) in the *Tokyo Women's Medical University* at Japan. The University of Helsinki is the institution that will be considered as the petitioner for carrying out the microprojects proposed.

The subject 'Manufacturing Technology' actually combines a variety of teaching/learning methods along with the learning through microprojects. Three of the seven topics are under the modality of microprojects. The remaining four topics use several teaching/learning techniques like real case solving problems, forum discussions, oral presentations, workshop practices and quizzes.

➢ Topic 1: Introduction.	
➢ Topic 2: Metrology.	
➢ Topic 3: Machining processes.	
➢ Topic 4: Moulding.	Microproject 1
➢ Topic 5: Welding.	
➢ Topic 6: Metal forming processes.	Microproject 2
➢ Topic 7: Advanced manufacturing processes.	Microproject 3

Figure 5. Main topics of the subject 'Manufacturing Technology' highlighting those related to the microprojects

The three microprojects are described as follows:

- *Microproject 1: Filling process analysis of the plastic injection of a piece*. The objective of the project is to analyse the plastic injection of a component under different process conditions, using the specific software Simulation Moldflow Adviser Ultimate 2014®, which is a free-student-download software. The students have to learn about plastic injection moulding and simulate the process, using one or two gates for injection. They are asked to report about some topics such as the filling time, injection pressure, surface orientation of molecules, weld lines, possible defects, etc. This microproject is linked to the seminar 'CAE (CAD) tools for modelling polymers in the automotive industry' given by an expert from the automotive industry.
- *Microproject 2: Metal forming processes*. Forging, cold rolling, blanking and deep-drawing are presented as sequential processes involved in the manufacturing of a cylindrical cup. Students must analyse each process and define their main parameters such as the press power, rolling force, appropriate punch and die diameters, and the holding force in order to obtain the final product (the cylindrical cup). This microproject is linked to the seminar 'Mould and die design for sheet metal plastic forming' given by a external mould-maker expert from a local industry.
- *Microproject 3: 3D Printer*. This project introduces additive manufacturing in the shape of 3D printing to students, from CAD modelling to G-code generation and the communication with the 3D printer. The project makes extensive use of University of Helsinki expertise in this manufacturing technique, which is used for cell bioprinting in tissue regeneration. The software used was *Repetier-host* (http://www.repetier.com), which allows completing all the necessary steps for 3D printing and is available for free download. In this project, students were asked to import the CAD model of the piece to be printed to the software *Repetier*, varying the parameters in the *Repetier* to meet requirements, print the piece and report about the process, time and cost required for printing. This microproject is linked

to the seminar ‘The future of 3D printing in regenerative medicine and tissue engineering’ given by two experts on additive manufacturing applied to regenerative medicine (**¡Error! No se encuentra el origen de la referencia.**).

Figure 6. Pictures of seminar linked to the microproject 3 (3D printer): “The future of 3D printing in regenerative medicine and tissue engineering" given by PhD. Andrés Sanz García (videoconferencing from Tokyo Women’s Medical University) and Eng. Enrique Sodupe Ortega (in the room)

All microprojects’ formulation followed a similar scheme:

1. *Introduction*: A brief introduction of the work to do is presented to the students. A scheme representing the overall proceeding to be followed by the students is also included.
2. *Objective*: The aim of the microproject is specified here.
3. *Deadline*: The closing date for submissions is set here.
4. *Submission procedure*: The link to upload the report is given to the students. Also the file format and size limit is informed in this section.
5. *Software*: A description of the software to be used, the link to download it (always freeware is proposed), and computer requirement (if needed) are presented in this section.
6. *Problem description*: The specific questions that have to be answered by the students are presented herein.

As an example of microprojects’ formulation, the statement of Microproject 3 is presented in the following paragraph.

Microproject 3. 3D PRINTER

1. *INTRODUCTION:*

If you have a 3d printer, you need to feed it with data. The open licence software 'Repetier' (http://www.repetier.com) is used to setup the 3D printer to create three dimensional parts. This software contains the three necessary software to make possible the setup:

a. **The slicer software**: which slices the 3D part and generates the G-code that contains the paths and speeds the 3D printer will follow during the printing. 'Repetier' uses the 'Slic3r' software.

b. **The host software**: that communicates the G-code to the printer. 'Repetier' uses its own software, 'Repetier-host'.

c. **The firmware**: which establishes the physical behaviour of your printer according to the G-code? 'Repetier' uses its own software, 'Repetier-firmware'.

Figure 1. Workflow for printing in a 3D printer

2. *OBJECTIVE:*
The aim of the proposed microproject is to import the assigned part into the 'Repetier' software and set the necessary parameters to print the part in one of the most used material: PLA. Each team will provide a report answering the proposed questions, including images of the imported part, the slicing of the part and the printed part. Also the G-code files will be provided. The part will be printed in the RepRap BCN printer available in the 'Metrology Lab'. The assigned part for each team in presented in *Table 1***¡Error! No se encuentra el origen de la referencia.**. The parts have been obtained from the web page http://www.thingiverse.com.

3. *DEADLINE:*
January 15th, 2015.

4. *SUBMISSION PROCEDURE:*
Upload the report and G-code files compressed in a .zip file, on the course's web page, through the appropriate link located in the section: 'Tema 7'.

5. *SOFTWARE:*

The software that will be used to solve this microproject is the 'Repetier-host V1.06'. You can download it from the course's web page or from the product official web page (http://www.repetier.com/download/). As depicted in *Figure 1*, the typical workflow is as follows:

1) *Create a 3d model and export it in .stl format or get it from the internet.*
2) *Arrange one or more models on a virtual print plate.*
3) *Slice the models into thin slices and compute a path for printer head. This is done by the slicing software, which converts the model into g-code, the language your printer speaks.*
4) *Check the created g-code for errors and printability.*
5) *Send the G-code to your printer or copy the code to an SD card, which can be inserted into your printer.*
6) *Monitor the printing.*

Except for point 1 'Repetier' offers everything you need. As you will see, the host interface offers different tabs to guide you easily through the workflow.

6. *PROBLEM DESCRIPTION*

The part assigned in *Table 1* will be printed in PLA using the RepRapBCN, located in the "Metrology Lab".

The printer has the following specifications:

- Printer type: Classic Printer.
- Number of Extruders: 1.
- Filament diameter: 2.92 mm (the standard value is 3 mm, but this value is used for the RepRapBCN Extruder)
- Extruder nozzle diameter: 0.4 mm
- Heated bed dimensions: 230 x 210 mm (to set the minimum and maximum value for X and Y coordinates)
- Printer Area Width: 200 mm
- Printer Area Depth: 200 mm
- Printer Area Height: 100 mm
- Cooling system available.

Open the 'Repetier' software and 'Config' the 'Printer Shape' according to the dimentions of your 3D clasic printer.

Go to the 'Slicer' tab and open the "Configuration" window. Load the RepRapBCN configuration file into all tabs: "PLA_HQ_0314.ini". This is the suited configuration to print high quality (HQ) pieces using PLA into the RepRapBCN. This is neccesary to be verifyed:

- Right temperatures for the PLA filament:
  - Extruder: first layer 215ºC, other layers 210ºC.
  - Bed: first layer 55ºC, other layers 40ºC.
- A fill density of 0.20 (or 20%).
- An inside fill pattern type: Rectilinear.
- A top and bottom fill pattern type: Rectilinear.

Import the part into the Repetier software ('Load'). Slice the part with 'Slic3r' software. Print the part in the 3D printer.

Provide the following information in a report:

1) Provide images of the imported part.
2) Provide images of the sliced part. Show the whole part and the most interesting sections: bottom, top, and some sections in the middle. Please clearly show the rectilinear pattern designed.
3) Provide the G-code for the part.
4) How much filament will be used?
5) If the cost of the filament is 0.025€/cm^3 for PLA, how much it will cost to print the parts?
6) How much time will take to print the part?

7) Provide a picture of the printing process on the RepRapBCN.
8) Provide a picture of the final printed part, held by the members of the group.
9) How much time was actually used to print the part?

As aforementioned in the description of the methodology, the evaluation sheets are also provided to the students so they can know how the results will be assesed. The evaluation record proposed for the Microproject number 3 is presented in Figure 7.

PRODUCT	*SCORE*
A. Written report: clarity, appearance, orthography.	0.5
B. Information requested	
B.1. Provide images of the imported part.	0.5
B.2. Provide images of the sliced part. Show the whole part and the most interesting sections: bottom, top, and some sections in the middle. Please clearly show the rectilinear pattern designed.	1.5
B.3. Provide the G-code for the part.	1
B.4. How much filament will be used?	1
B.5. If the cost of the filament is 0.025€/cm3 for PLA, how much it will cost to print the parts?	1
B.6. How much time will take to print the part?	1
B.7. Provide a picture of the printing process on the RepRapBCN.	1
B.8. Provide a picture of the final printed part, held by the members of the group.	1.5
B.9. How much time was actually used to print the part?	1
TOTAL	**10**

Figure 7. Evaluation sheet for the Microproject number 3

The Microproject 3 (3D printer) was the most motivating for the students. The fact that they could manufacture one piece completely using freeware and a real RepRap 3D printer was a satisfactory experience for them (**Figure 8**).

Figure 8. Pictures of some of the groups of students proudly showing their 3D printed piece

Results and Discussion

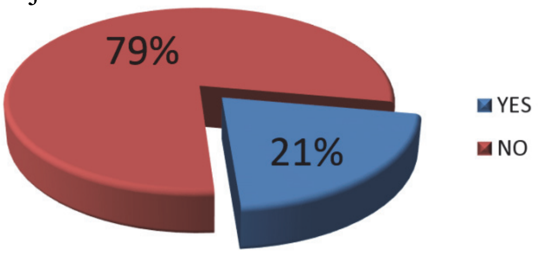
The implementation and subsequent analysis of the teaching/learning experience proposed provided us several observations that are carefully discussed in following paragraphs:

- Students complement the theoretical and practical knowledge acquired during both the lessons and the practical classes with a realistic vision of working by projects. As verified by Rodriguez *et al.* (2015), this system involves many tasks such as information research, self-learning and self-management, along with other competences like teamwork. Moreover, students must confront situations where the definition of the scope, the correct understanding of the proposed requirements, and the deadlines must match with the correct resolution of the proposed project.
- Collaboration with international organizations, in this particular case the *Division of Pharmaceutical Biosciences* at the University of Helsinki, provides an open vision that enriches the student learning through different techniques such as the use of ICTs as communication and contact methods. The student must overcome language barriers and use the main international and scientific language English as his main vehicle for communication. Moreover, the student must confront the cultural differences and problems due to different working hours. These positive implications of multidisciplinary and multicultural project frame have been also proven in the work of Heikkinen J. and Isomöttönen (2015).

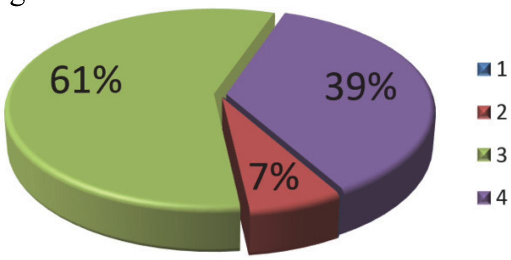
  The collaboration with the international entities such as the University of Helsinki provides students the possibility to be in contact to modern fabrication technologies such as *additive manufacturing,* and more specifically, 3D bioprinting machines. Students greatly value this because it allows them to use more innovative methods, which is a motivating experience for students. Gilbert *et al.* (2015) also highlighted these advantages in the development of an international project-based learning. In that case, students work together in addressing power balances, economic and social issues and overall sustainability of international development projects.
- The interrelation between different manufacturing technologies, which are traditionally linked to industrial engineering, and a specific area of knowledge drastically different such as biomedicine, can give students an innovative vision of the wide spectrum of applications in which manufacturing methods can be involved. Additionally, students have to cope with an unknown discipline.
- Lastly, the technical seminars provide an interactive tool for students with experts from industry and international institutions. This increases their motivation for the acquisition of new knowledge.

Once the semester has already finished, students filled a survey to evaluate their interest in the presented teaching/learning methodology based on microprojects in contrast to the traditional methods. **Figure 9** depicts the results from that survey showing that the use of English does not represent an important barrier to properly develop the objectives of the microprojects. Besides, the percentage of students that considers of high or very high interest learning through microprojects increased from 82 to 93% with respect to last year. This can be explained in terms of the important number of improvements introduced such as glossaries, evaluation sheet, the 3D printing machines and the seminars given by experts (86% of the students considered them of high or very high interest). Consequently, it can be said that the subject becomes more extensive and global. It is also derived from **Figure 9** the importance of printing the designed pieces to motivate the students along the process.

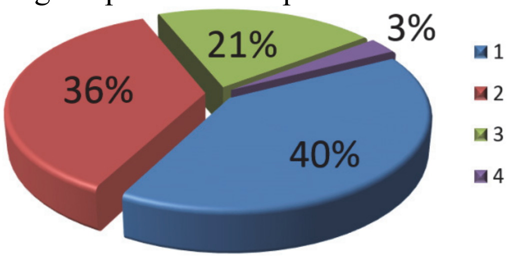
1. Do you consider the use of English a great language barrier to develop the tasks along the microprojects?



2. From 1 to 4 (where 1 represents 'low' and 4 'very high'), how interesting did you find the microprojects based teaching/learning methodology compared to traditional teaching model?



3. From 1 to 4 (where 1 represents 'low' and 4 'very high'), how important was the possibility of printing the piece in a 3D printer?



4. From 1 to 4 (where 1 represents 'low' and 4 'very high'), How interesting were the seminars given by experts during the course?

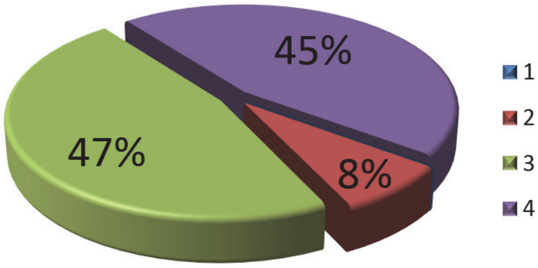


Figure 9. Plots with the percentages obtained from the final survey of the course 2014/2015

An additional question was also included in the survey, asking the students their own opinion about how the proposed microprojects' methodology could be improved. From these answers some enhancements could be added to the new course: glossaries, evaluation sheets, more information on the subject, more 3D printers, etc. For next course the suggestion of visiting a manufacturing company related to the microprojects is considered. We are in contact to several industries of the region interested in collaborating with us: one is related to the plastic injection moulding (field related to Microproject 1 and 2), the other is involved on rubber extrusion for the automotive industry (field related to Microproject 1) and the last one is related to 3D printing (field related to Microproject 3).

During the development of the microprojects, students are encouraged to propose new ideas to improve the processes studied on materials, design alternatives, assembly systems, software, and so on. Those considered the best initiatives are then implemented. Last year, several ideas to improve the 3D printer were carried out. For instance, an automatic levelling system based on inductive sensors was installed in the printer (**Figure 10**). An additional example was a novel proposal by one of the students that consisted on building an ultra-economic 3D printer for 100 €. The price of a standard RepRap printer is around 450 €. It was decided to provide the student with the needed support for the development of the design proposed. Lastly, other ideas were related with the printing of special materials such as paste materials (hydrogels, ceramic, chocolate, etc.). To this end, and in future courses, the incorporation of a paste extruder should also be considered.

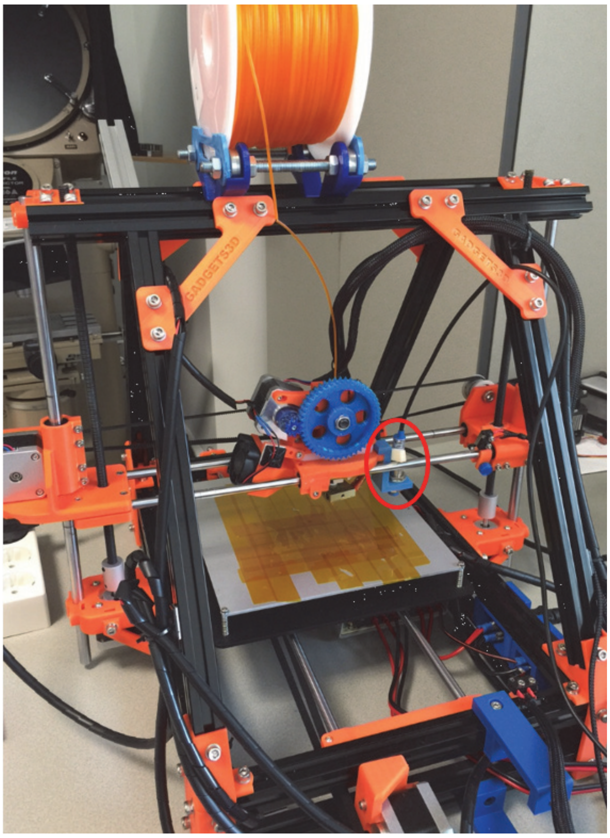


Figure 10. 'Mendel Max' 3D printer with inductive sensor for auto-levelling

Finally, Figure 11 shows the average score and success rates of the subject studied during previous semesters from 2007 to 2014. More specifically, we should speak about the periods before and after implementing microproject teaching/learning methodology. The traditional teaching model was used during years 2007-208 and 2009-2010, and the microproject methodology was implemented in 2013-2014 and 2014-2015.

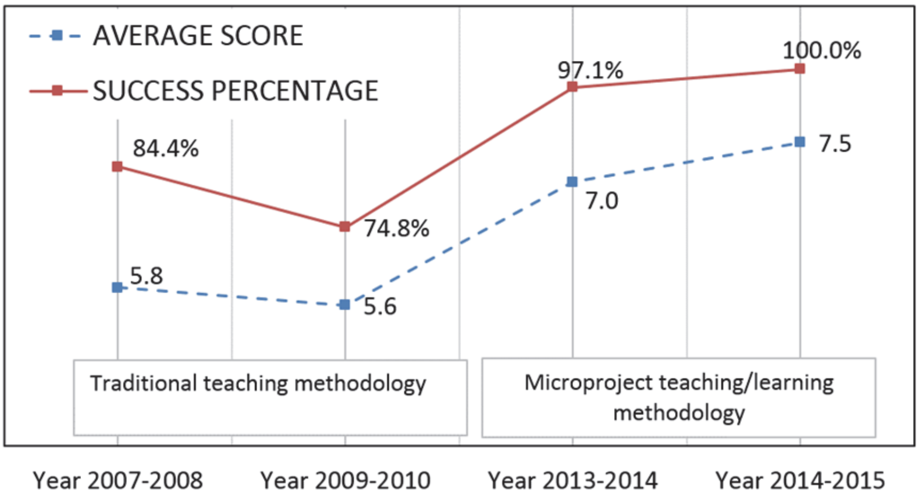


Figure 11. "Manufacturing Technology" subject average score and success rate for years from 2007 to 2014.

The results obtained in this course (2014-2015) and in the previous one (2013-2014) show that the average scores and success rate drastically rise when applying the microproject-based methodology proposed. Interestingly, last year 100% of success was achieved with the new methodology. According to these results, the convenience of the microproject teaching/learning model herein proposed for technical subject seems to be clearly demonstrated.

Conclusions

This paper presents the use of small projects also well known as microprojects that are requested by foreign institutions with the goal of bringing the working world to inexperienced undergraduate students. Following specific scopes and using teamwork, they must deliver reports with appropriate technical solutions under strict deadlines by. One of the main characteristics of the proposed project is the use of English language as well as the promotion of ICTs as useful tools. These elements are complemented with seminars by experts on different fields.

The methodology proposed was applied to the subject 'Manufacturing Technology', in cooperation with the *Pharmaceutical Biosciences (University of Helsinki)*. Students showed higher satisfaction with this educational method than using the traditional teaching system. Also, the collaboration with real petitioners gave students an extra motivation as they made use of their expertise solving real-world problems in industry.

Finally, although the methodology was just applied to the subject 'Manufacturing Technology', it might be applicable to other subjects in technical degrees. The international mobility of researchers, who acted as foreign petitioners in this experience, can play an important role to connect universities, companies and research centres worldwide in future.

Acknowledgements

The authors would like to acknowledge University of La Rioja for the financial support received through the program '*Proyectos de Innovación Docente 2014/2015*', as well as for the fellowships *FPI-UR* to train researchers (J. Fernandez-Ceniceros and F. Antoñanzas-Torres). The authors also want to express their gratitude to the *Instituto de Estudios Riojanos* (IER), to the *Banco Santander* for the project *PROFAI 13/06* and to the *Agencia de Desarrollo Económico de La Rioja* for the project *ADER-2012-I-IDD-00126* (CONOBUILD). One of the authors, A.S.G., would also like to acknowledge the financial support with the grant No. 273689 (*FINSKIN*) and the mobility grants No. 276371 (*VATURP*) and No. 286793 (*VASCBIOEXP*) by the Academy of Finland. We would like to thank to the special collaboration of all student involved in this experience. Their comments and suggestions enriched the methodology proposed in this article.

References

Aliane, N. & Bemposta, S. (2008). A learning experience based on projects for Robotics. *Ibero-American Magazine of Learning Technologies*, 3(2), 71.

Buck Institute for Education, An overview of Project Based Learning (2002). http://www.bie.org/pbl

European Space of Higher Education. http://www.eees.es/

Fernandez-Ceniceros, J., Sanz-Garcia, A., Urraca-Valle, R., Martinez-de-Pison-Ascacibar, F. J. & Pernia-Espinoza, A. V. (2014). Teaching-learning model based on micro-projects for the subject 'Manufacturing Technology'. *XXII University Congress on Educational Innovation on Technical Studies*, Almaden (Spain).

Garcia-Almiñana, D. & Amante, B. (2006). Experiences of implementation of cooperative learning and learning based of projects. *I Seminar on Educational Innovation*, Zamora (Spain).

Gary K. (2015). Project-Based Learning. *Computer*. 48 (9), 98-100.

Han S., Capraro R. & Capraro M. (2015). How science, technology, engineering, and mathematics (STEM) project-based learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement. *International Journal of Science and Mathematics Education*, 13 (5), 1089-1113.

Gilbert D., Lehman M., Ellzey J., Bailey W. & Young L. (2015). Teaching 'community engagement' in engineering education for international development: Integration of an interdisciplinary social work curriculum. *European Journal of Engineering Education*. 40 (3), 256-266.

Heikkinen J. & Isomöttönen V. (2015). Learning mechanisms in multidisciplinary teamwork with real customers and open-ended problems. *European Journal of Engineering Education*, 15 (6), 653-670.

Labra, J. E., Fernandez, D., Clavo, J. & Cernuda, A. (2006). A learning experience based on projects using open-source software development collaborative tools. *XII Seminar on University Education of Informatics*, Bilbao (Spain).

Marti, J. A., Heydrich, M., Rojas, M. & Hernandez, A. (2010). Learning based on projects: an educational innovation experience. *University EAFIT Magazine*, 46(158), 11.

Moodle: Open-source Learning Platform. http://moodle.org/

Nunan D. (1989). Design Tasks for the Communicative Classroom. *Cambridge University Press*.

Repetier: the software driving your 3D printer. http://www.repetier.com

Rivas, F.C. (2006). Learning platform Moodle as a tool for social work in the European Space of Higher Education context. *Social Actions and Research*, 1, 367.

Villalba, G., Zamora, M. A., Santa, J. & Herrero, D. (2009). Experiences on learning implementation based on projects to develop creativity in domotics subjects. *IX Seminar on Cooperative Learning and II Seminar on Educational Innovation*, Almeria (Spain).

Young M. (2014). Developing English Communicative Ability for Science Gifted Students through Project-based Learning of Publishing English Newspapers. *The Journal of the Korea Contents Association*, 14 (5), 273-286.

Chapter 13

Assessing the Project Based Learning methodology in Materials Science courses within an inter-university educational network

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Abstract: One of the peculiarities of the present Information and Communication Society is its complexity and changing character. Within this new model of society, our education systems require a substantial change in their goals and practices. Thus it is necessary for teachers and lecturers to adapt to this reality and propose changes on one of the key elements of the curriculum: a methodology in which the student must be the real axis of university education and the teacher a mediator or guide the process. Among the methods that facilitate this transition, the Project Based Learning (PBL) allows learning different basic and/or specific skills, such as interdisciplinary teamwork, personal relationships, ethical commitment or critical thinking. In this paper, we present a proposal for educational innovation based on PBL methodology. The methodology isdeveloped with the aim of analyzing its viability in core Materials Sciencecoursesin different Engineering degrees in Spain. Specifically, it presents a PBL experience carried out simultaneously by lecturers and professors of Materials Science in four Spanish public universities. The subject of the PBL has been tailored for each curriculum. The results show that this methodology arouses more interest among students than the traditional methodology, while allowing transversal competences to be developed as well as providing a new way to evaluate them.

Keywords: Project Based Learning (PBL); Inter-university; Materials Science

Introduction

A new educational paradigm

The information and knowledge society entails a culture sustained by globalization processes involving, among others, the acquisition and assimilation of new knowledge, new ways of seeing the world, the use of new tools and languages, etc.

requiring therefore great efforts and skills that facilitate adaptation to this complex and changing scenery (Castells, 1996). The educational systems within the European Higher Education Area (EHEA) require models of teaching and learning to meet the demands of this new paradigm. In this sense, educational institutions must consider three fundamental aspects that facilitate the transition to these social and educational models (see Figure 1) (Pozo, 2006). First, be aware that the formal environments are no longer the primary, and sometimes not even the main, source of knowledge. Lecturers and teachers must attend and recognize learning from non-formal and casual spaces. Second, understand that knowledge is multiple and uncertain. The large amount of information that can be accessed raises new skills such as search, evaluate, organise, select and use all this information to be really valid, useful and productive. Finally, it must be considered that learning is a continuous process and extended along life. The world of work demands new requirements; the efficient performance of a profession requires solving tasks in an increasingly higher level, and the link between education and job career every day becomes more urgent.

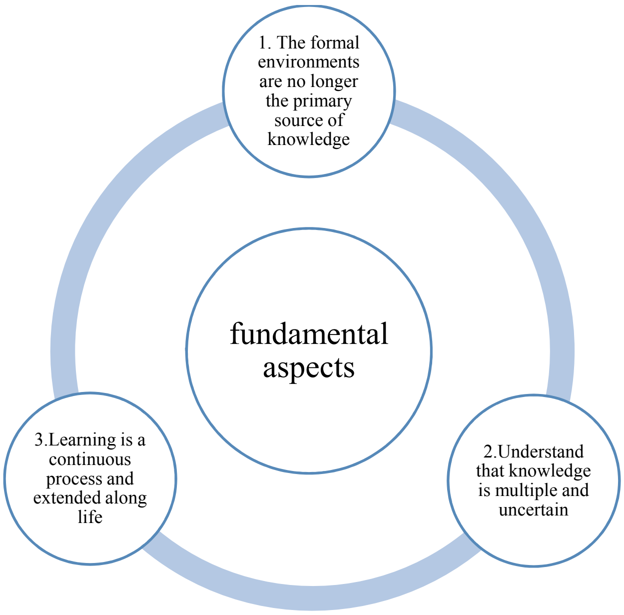

Figure 1. Fundamental aspects that facilitate the transition to these social and educational models

In addition to these considerations, we must follow the assumptions made by Delors in his report, not just about learning to learn, but learning to do, learning to be and learning to live together (Delors, 1996). This holistic and integrated view of education intends to train citizens that are competent and able to adapt to the social context of change, complexity and uncertainty.

All these ingredients, cooperation, peer learning and skills such as learning to learn or selection and analysis of information, can only be achieved by democratizing the teaching - learning and applying methods of learning that increase activity and participation of the students, who are the real protagonists.

Project Based Learning: basics

Once described the current educational context the authors believe that a good tool to address this issue is the Project Based Learning (PBL).

PBL is an instructional model originally developed in medical school programs (Barrows and Tamblyn, 1980). Specifically, it first appears in the Faculty of Medicine at McMaster University in Canada in the mid-60s of the twentieth century. Future medicine professionals must acquire, in addition to knowledge, a range of basic skills and competences to carry out their work comprehensively. This new approach was spread to other fields such as legal sciences or engineering and reached Europe ten years later (Zhang, Colmos and De Graaf, 2013).

There are many definitions of PBL. Basically, they all agree in defining it as a model of learning in which students raise, implement and evaluate projects that have an application in the real world. PBL emerges as an innovative approach that has its roots in constructivism, and in which, from an initial problem, can develop a creative work of finding solutions or read into the situation under study.(Fernandez *et al.*, 2006).

As stated above, PBL is based on the constructivist theory of learning, thus indicating that knowledge is actively build by the student, and the knowledge, which is continuously in motion and change, is incorporated by study tools and theoretical and practical assimilation, causing the student to be set up as an active player, aware and responsible for its own learning.

(Santillán, 2006). In PBLapproach, cognitive autonomy is encouraged, taught and learned from problems that are meaningful to students; misunderstandings are used as an opportunity to learn more and not to penalize; and a significant value to theself-assessment and formative, qualitative and individualized assessment is given. (Dueñas, 2001).

This method uses problems as a starting point for the acquisition and integration of new knowledge (Barrows, 1986). As other methodologies, it requires a series of well-structured and planned steps set by the teacher.

Moust, Bouhuijs and Schmidt (2007) and Schmidt (1983) proposed seven steps to implement the resolution of the project:

1. Clarification of concepts and terms that appear in the proposal project from the dialogue between group members.
2. First tentative definition of the problem. After steps 3 and 4 this step can be repeated if considered necessary.
3. Analysis of the problem from the contributions of all group members through brainstorming.
4. Development of a systematic summary with several explanations to the analysis of the previous step. Once generated the greatest number of ideas about the problem, the group tries to systematize and organize them, highlighting the possible associations among them.
5. Set up of learning objectives and common decision on aspects of the problem, which are to be investigated and understood.
6. Search for more information, individually.Synthesis of collected information and writing a report on the acquired knowledge.

Figure 2 shows a diagram summarising each of these steps.

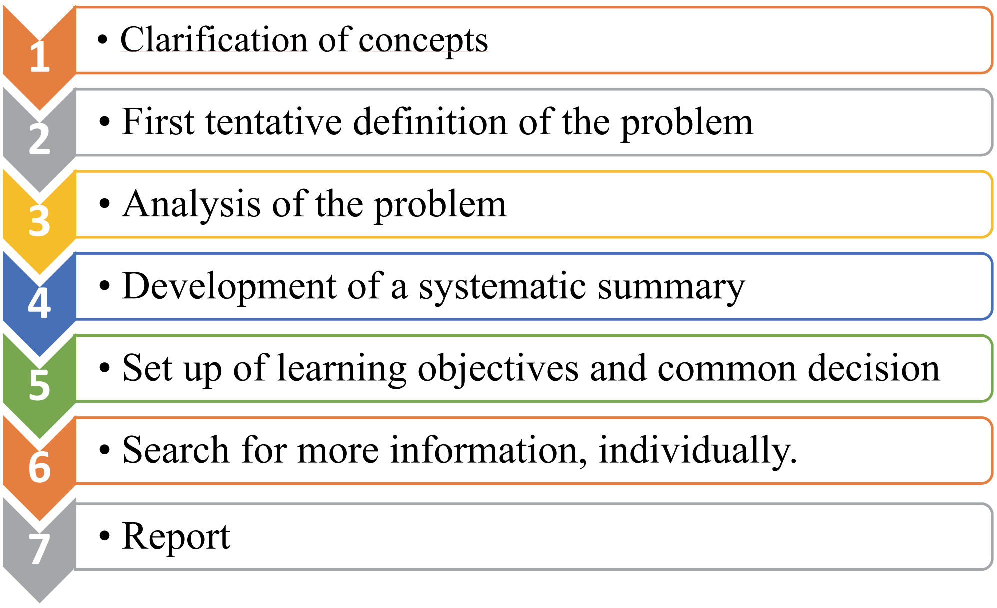

Figure 2. Diagram with all the steps followed in PBL

Before implementing PBL, educators should bear in mind a number of key points. The students should have enough knowledge to support their future learning. The project to be studied in the PBL must be as similar as possible to the professional work as engineers. This will ensure that students do not get disappointed with the activity. The level of difficulty should be a challenge for the students and yield many questions. Nevertheless it must also be achievable so that students remain motivated during the course. In addition, the teaching-learning environment must encourage both independent learning and team working. Accordingly, team working activities need to be guided and coordinated by the educator. Students should be introduced into basic team working rules such as roll distribution, responsibility, time management, mutual dependence support and mutual task requesting. Correct roll distribution will help to foster good relations within the group. Responsibility will be key to the success of the PBL activity. Time management should be encouraged through the PBL and the other course activities and will be a very valuable skill not only during the university period but also for the student's future. Mutual dependence support makes the best students to help those who struggle more with the material. In addition, the best students gain confidence while helping their peers in the learning process. Mutual task requesting means that all group members need to be involved in the PBL.

The length and depth of the project should be carefully regulated prior to the starting of the PBL activity, both in terms of objectives and in terms of work load. An excessively long or deep project would be detrimental for the rest of the courses taken by the student because too much time devoted to on one particular course means too little time devoted to the rest of the courses. Moreover the distribution of the work load during the duration of the activity should be adjusted so that the time spent by the students correlates to the number of credits of the course.

Given that 1 ECTS requires 25 hours of student work, the approximate number of hours that students need to spend on a 6 ECTS course is 150. Let us consider a 6 ECTS course where the PBL weight is 30%. For this course, the student should allocate 45 hours to the PBL. Within these 45 hours, 18 hours should happened in the classroom. Accordingly each student should allocate 27 hours to work outside the classroom on the PBL. Most authors agree that PBL should have duration of 8 weeks (Lesperance, 2008). Therefore, for a 6 ECTS course, the PBL weekly work load outside the classroom should be 3.4 hours. This means that students should be able to get a very good mark on the PBL by devoting 3.4 hours on average for the duration of the PBL. This figure does not need to be exactly 3.4 hours every single week, but it is very useful as a first estimation of PBL weekly work load.

The educator roll in PBL activities is as important as in traditional lecturing but for different reasons. Unlike in non-interactive learning approaches, the educator roll is crucial as a mediator and facilitator of the learning process.

These phases point the many cognitive processes and competencies required to the students. As already mentioned above, from the organization of work the student develops skills such as problem solving, decision making, teamwork and communication (Michael, 2005). Thus, knowledge is gained while they learn to learn in a progressively independent way as well as they learn to apply that knowledge in solving various problems similar to those they face in the performance of different facets of this work: working in teams under supervision, being progressively autonomous, identifying learning goals, managing time effectively, identifying which aspects of the problem can be ignored or need to explore more deeply and investigating on their own, thus directing their own learning. Through this process, they benefit from the participating peers, which provide the necessary contrast to their inquiries and ways of understanding what they are studying (Vizcarro and Juárez, 2009).

The review by Schaffer, Chen and Oakes (2012), describes how researchers in many disciplines have investigated the efficiency change in project-based learning environments. For example, project-based learning influences student efficacy for academic knowledge in medical education (Papinczak, Young, Groves, and Heynes, 2007), communication and cultural knowledge in foreign language learning, and collaboration in software design engineering (Dunlap, 2005). However, other researchers have reported mixed results on the direction of the self-efficacy change. Prior research on self-efficacy in a project-based learning environment suggests that the quality of PBL experiences impacts students' self-efficacy (Dunlap, 2005). Mills (2009) investigated students' efficacy in a language learning course and found significant increases in student self-efficacy in the areas of "communication, cultures, connections, comparisons, and communities" after participation in a project-based learning curriculum. This research concluded that positive experiences will lead to an increase of self-efficacy, while stressful or fearful experiences will lead to a reduction of self-efficacy.

One of the strengths that characterize the PBL is its application to different educational levels as well as its versatility to be able to deal with various areas of knowledge. The literature review offers examples of these benefits. Reeves and Laffey (1999) used PBL in an Introduction to Engineering lecture and found an increase in the students' problem-solving skills. However, its implementation in the Materials Science knowledge area is not very common, being that one of the most traditional engineering courses and where the introduction of non-traditional teaching methods such as PBLseems to be more difficult. In this sense, Jonassen and Kanna (Jonassen and Khanna, 2011) have analyzed the feasibility of introducing a similar methodology (PBL) in a course in the field of Materials Science for mechanical engineers at the University of Missouri and have found that this methodology is very difficult to implement unless this introduction is carried out in curricular way. Thus, their findings show that the introduction of this methodology in only one course(for this type of degrees) requires great effort from both parties involved: teachers and students, whereas if the methodology is implemented at the level of curriculum for the whole degree, it is much more effective than the traditional learning methodologies.

Despite the predictable difficulty that would involve the implementation of this methodology in material science courses in engineering degrees, the potential benefits for the students motivated the authors to start this educational experience, addressed to study the feasibility of using PBL methodology in those courses in different degrees of Spanish public universities.

The experience is part of a network of educational innovation in Materials Science formed by teachers from seven Spanish public universities (IdM@ti) (see Figure 3). Within this network, it was decided to implement the PBL simultaneously on their respective courses, with the aim of analysing if it was possible to apply it in courses in this field, regardless the specific degree in which the course is given or any other particular situation of the university. The participating universities were University of the Basque Country-EuskalHerrikoUnibertsitatea (hereinafter UPV/EHU), Universitat Jaume I (hereinafter UJI), the University of Barcelona (hereinafter UB) and the University of Malaga (hereinafter UMA).

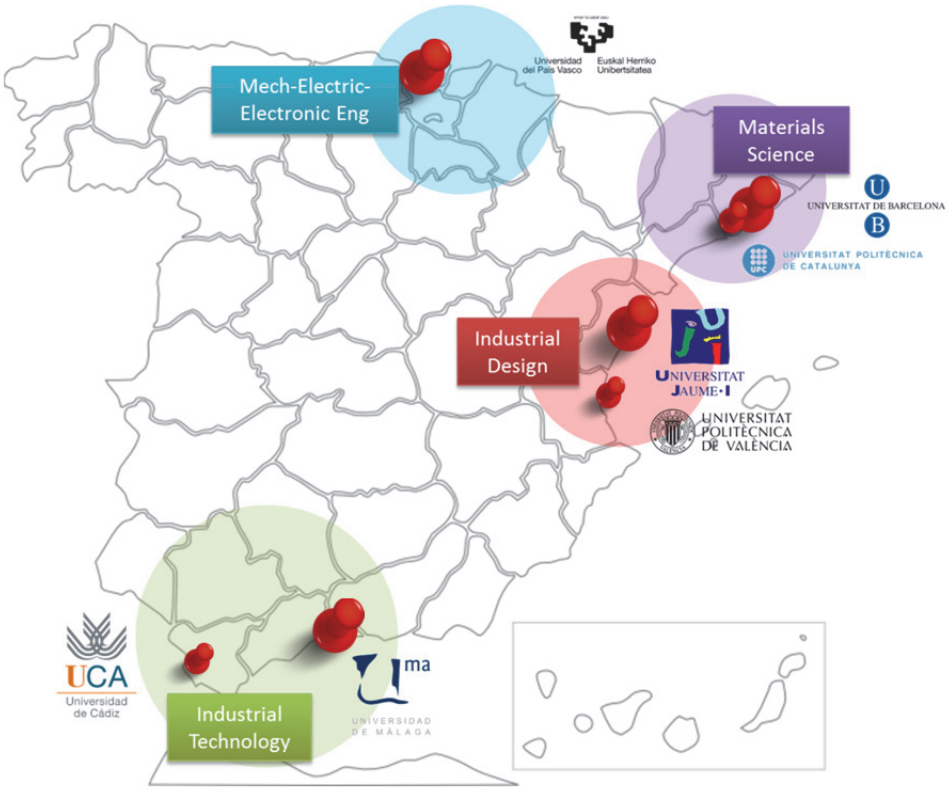

Figure 3. Approximate location in a map of Spain of the universities involved in the Network for Innovative Teaching in Materials Science (IdM@ti)

To the best of our knowledge, this experience is pioneer in Spain, both in the field of knowledge to which it applies, as for its inter-university character. So in this article we describe the essential elements of our proposal and bring some of the most interesting perceptions of the agents involved, faculty and students.

Methods

The activity was developed with students from four universities enrolled in different degrees studying four Materials Science related courses. Depending on the University, the Materials Science course was part of a different Engineering degree. This fact brings some aspects worth noting:

- Each engineering degree has a different curriculum, and consequently the level of the students' prior knowledge of the courses is different.
- Objectives and skills to develop in each course are different.
- All students involved in the current work were undergraduates from 2nd or 3rd year in Engineering (see Table 1) This implies different groups regarding the maturity of the students and miscellaneous group circumstances. Nevertheless, none of the students involved in the current research was studying first year engineering course. This meant that students were more driven to learn than in the first year. Two reasons were identified for this behaviour. On the one hand, first year in engineering degrees tend to be more theoretical and less readily applicable to the engineering world. For example, Algebra or Statistics courses are generally less popular among engineering students than Fluid Mechanics or Materials Science courses. On the other hand students taking part of this study have attended the University for at least 12 months. This means that they have all overcome the initial period which is a transition between secondary school and university studies.
- The weight of the PBLactivity in the evaluation of the course is different in each university. Figure 4 summarises the weight of the PBL and other course activities in the different universities. Figure 4 shows that PBL weight ranges from 60% in UJI and UB to 20% in UMA. It is also worth noting that not all universities used the same activities to evaluate student's competences. Table 1 summarizes the casuistry.

Table 1. Curriculum of the students and group characteristics

University and degree	Course	Size of the main group	Number of students per working group.	Number of PBL groups.
UPV-EHU Industrial Engineerings (IngenieríasIndustriales)	MaterialsScience (Ciencia de materiales) (2º)	60	5	12
UJI Industrial Design and Product Development (Diseño Industrial y (Desarrollo de Producto)	Materials II (Materiales II) (2º)	126	5	3
UB MaterialsEngineerings (Ingeniería de Materiales)	MaterialsLaboratory (Laboratorio de materiales) (3º)	16	4	4
UMA Industrial Design and Product Development (Diseño Industrial y Desarrollo de Producto)	MaterialsScience (Ciencia de materiales) (2º)	119	5	11

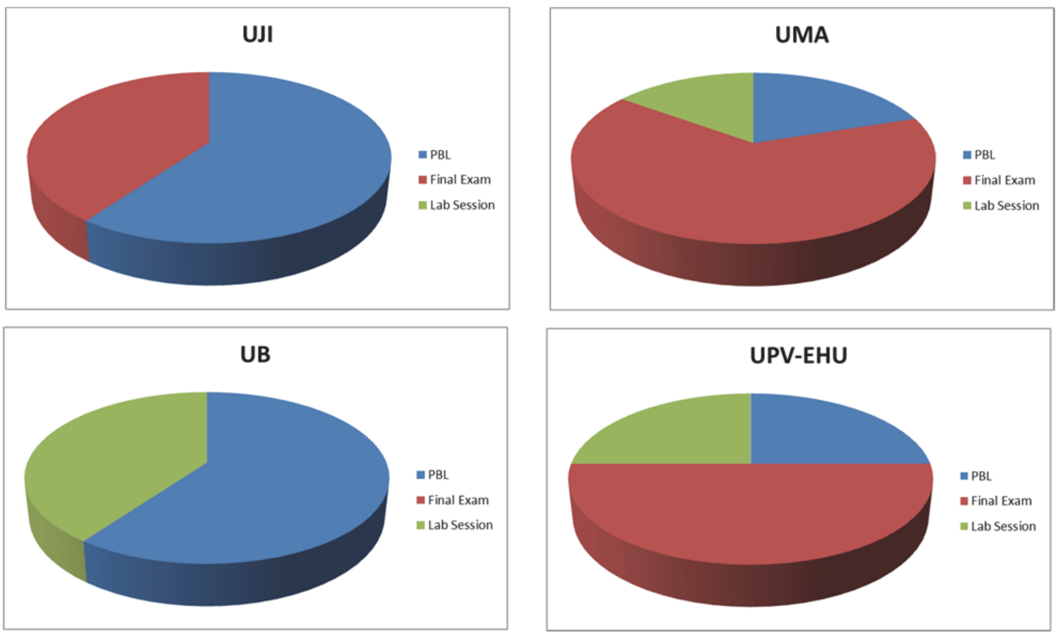

Figure 4. Weight distribution of different activities in the four different universities (UJI, UMA, UB and UPV-EHU). PBL weight is shown in plane colour, lab session's weight is shown in striped sectors and final exam weight is shown in dotted sectors

As a common element to all projects, the methodology is structured in three sections defined in the documentation provided to the students and summarised in Figure 5:

- The project and its objectives.
- A closed proposal with minimal requirements within and outside the classroom.
- The exact details of the evaluation methodology.

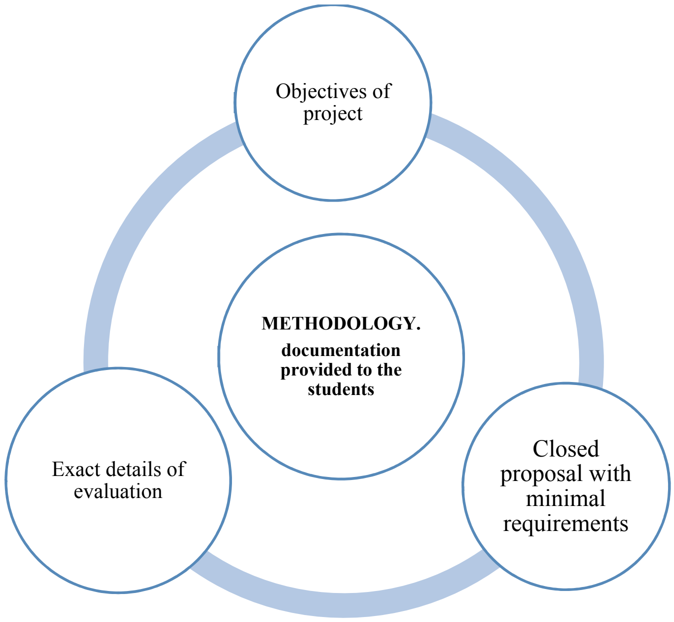

Figure 5. Summary of the three main sections described in the documentation given to the students

With such common minima, each participating university adapted the methodology to its needs and abilities.

The main focus of the project is to study the design of a commercial product, a razor blade (see Figure 6). To this end, students were given four different razor blades. They could then disassemble the blades and study each part of the blade independently from a Materials Science point of view. Razor blades were chosen so that a wide range of material families were studied. In addition students were asked to propose a novel design for a razor blade. The new design should be advantageous compared to the blades given to the students. The choice of such a product was based on the following criteria: be affordable for the development of the activity and involving a set of teaching materials of interest and ease to be disassembled and studied. Indeed, it was considered that this product was familiar to the students and easy to access to technical and commercial information over the Internet and the course bibliography.

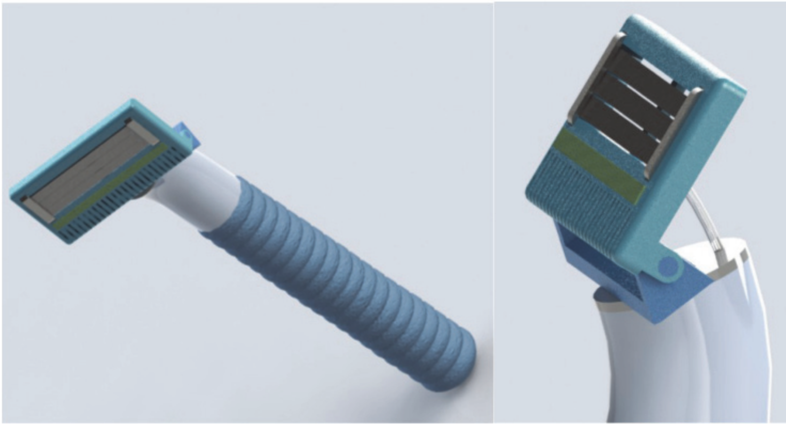

Figure 6. Example of razor blade product designed by the students in the UJ

While in the UPV/EHU and UB, the whole group of the course has performed the activity, in the UJI only 15 volunteer students have participated in it. The project was proposed only to a subgroup of high performance students because of the high volume of students enrolled in this course. The selection of them was based on a mixed approach between their average grades in all classes and a motivation letter that was asked to provide to those interested in participating. In the case of UMA, they also decided to implement the PBL activity in a fraction of the total students, as in the UJI, given that there were too many enrolled students. However, it was extended to a larger percentage of students (around 50% of total enrolment).

The different ways of selection of students to develop the PBL activity show advantages and disadvantages. On the one hand, a selected group does not allow a direct comparison of all results with the whole class, because of the differences in the student's motivation. On the other hand, this method can explore the behaviour and performance of students in slightly different contexts. This will allow drawing conclusions such as the suitability of the different ways of selecting students for participating in the PBL activity.

The project proposal varied slightly for each of the four centres in order to adapt it to the different student profiles. Thus, in the case of the UPV / EHU and UMA the statement was that the participants assumed the role of a group of students willing to take part in a contest organised by a major razor blades brand. The purpose was to look for a new design oriented to new market niches, either by consideration of groups of people, environmental considerations, innovative designs, improve some specific features of the blade, etc. Figure 7 shows three different examples of projects chosen by different groups. Since the PBL took part in Materials Science courses, all considerations had to have a link with the course. It was the lecturer's duty to guide group discussions so that students works on specific areas of the Materials Science course. This guidance was delivered a mediators, so that students felt a difference and engaged more with the course, as compared to more traditional learning approaches. Once formed the working groups, every member of each group would assume specific tasks, adopting: i) the role of industrial design engineer or ii) role of materials and process engineer. The UMA activity was conducted in coordination with another course, Industrial Processing. Therefore, special attention to the manufacturing processes used for each component of the blade was given. They also studied in detail the properties of all the materials used.

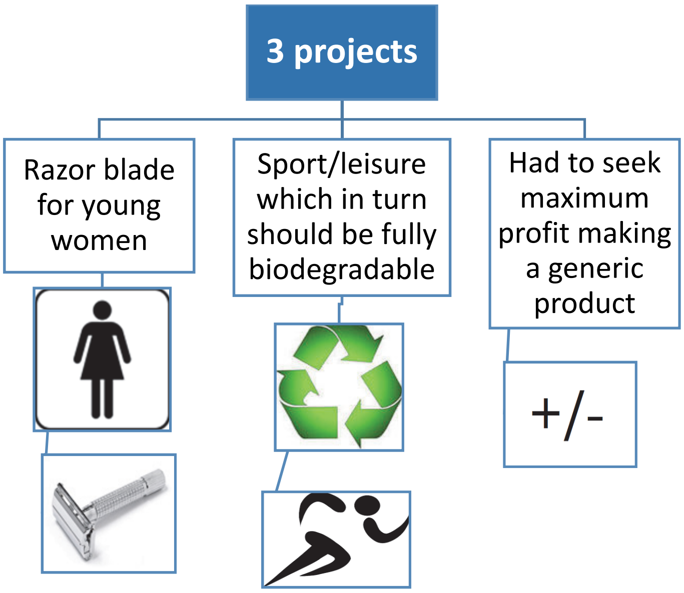

Figure 7. Examples of three different projects chosen by the students

At the UJI this activity was carried out in coordination with the course of Conceptual Design, which goes by simultaneously for the first half of the second year. The onset of the activity was proposed as a role playing game (RPG) in which each group was constituted as a design studio, while the teacher was the intermediary between them and the promoter. In this case, the promoter was a foreign razor company that aims to open markets in Spain. Each of the three groups was proposed a project that was slightly different from each other, looking for manufacturing blades intended for a very specific niche market. Thus, one group was asked to design a product for young women, other for sport/leisure which in turn should be fully biodegradable and the third group had to seek maximum profit making a generic product.

In the course of Materials Laboratory at UB, the stated objective was that the students were able to justify the choice of materials in three different commercial blades. As a selection criterion it was used the price-performance ratio evaluated using different experimental tests performed by students. The project was conducted in blended learning, combining laboratory sessions and study time of each student. Monitoring the work was carried out by conducting regular control meetings over the duration of the activity, as well as with the presentation of three "deliverables" throughout the activity. PBL activities also serve to train team working competences (Barbour, 2006). Team working skills can be trained by posing tasks to the student in such way that work load is divided in a fair way among the team members. In this work, division of tasks was encouraged by allocating different rolls to each team member. The four key rolls employed in this study were: i) head of the project; ii) design engineer; iii) technical engineer; and iv) materials and manufacturing engineer. The head of the project was in charge of the general coordination of the group. The technical engineer was in charge of drawings and analytical calculations.

The evaluation methodology was extensively detailed in the documentation provided for the project. A set of criteria to be evaluated in one or more of the activities, such as minutes of meetings, participation in wikis, ICT use, content and presentation videos, reports, etc. were defined In this way it was possible to conduct a competency assessment in agreement with the Bologna process (specific knowledge and transversal skills). However, each teacher had to adapt it to their university systems.

With the evaluation of various activities it was possible to draw a note, which had the weight in the final grade indicated in table 1. This percentage is the key to the development of the activity, since it has been shown that when the activity has no weight in the final grade the motivation of a large majority of students decreases dramatically (Antepohl, Herzig, 1997). Internal assessment within the faculties involved in this work was performed in two ways:

- Surveys conducted among the students to evaluate the degree of acceptance of the PBL methodology and the perception of how this methodology helps them to achieve the course competences.
- Faculty meetings mainly during annual IdM@ti workshops in order to share experiences, detect problems, introduce improvement proposals, and involve other universities.

Results and Discussion

Acceptance of the project and the involvement of students had different nuances in each university. In the UPV/EHU and in the UMA it has been good (3.9 and 4.0 out of 5 respectively in a Likert scale); students generally have welcomed with interest the project although the degree of involvement has been uneven. At the UB it has been noticed that as they were senior students and small groups, their involvement was very high and so was the quality of their work. With respect to the level of acceptance the result obtained was very high (4.3 out of 5 in a Likert scale). At the UJI, as it was a volunteer project with the most motivated students, their reception was excellent (4.8 out of 5 in a Likert scale) and the students were involved very much. Nevertheless, the average number of hours dedicated to the project exceeded 15% the plan. It was also noticed a certain degree of competitiveness that we believe may be beneficial since it reflects a personal involvement with the project and desire to excel. A direct correlation between the number of students involved in the PBL activity and the level of involvement and student motivation is observed then. In most cases, it was observed that students participating on PBL activities were more engaged with the course material. Possibly this behaviour comes motivated by greater attention to the student by the teacher. A similar trend between the percentage of PBL activity on the final grade for the course and the level of involvement and student motivation is observed.

The project has eased to find objective ways to evaluate transversal competences as well as its evolution over the semester in the four universities. This process involves a change in evaluation methodology, hard to implement in the field of engineering.

It has been observed that the level reached in the competences of specific knowledge of the course during the PBL activity had direct positive relationship in the outcome of the evaluation of the same competences by traditional methods (development of a written answer to a question). A plot of the grades obtained in the exam versus the grades of the PBL activity for the students in the UB is shown in Fig. 8. Fig. 8 also shows a linear trend fitted to all the data points. The positive slope of the line clearly shows that the students with higher grades in the PBL activity achieved also better results in the conventional evaluation method (i.e. the exam).

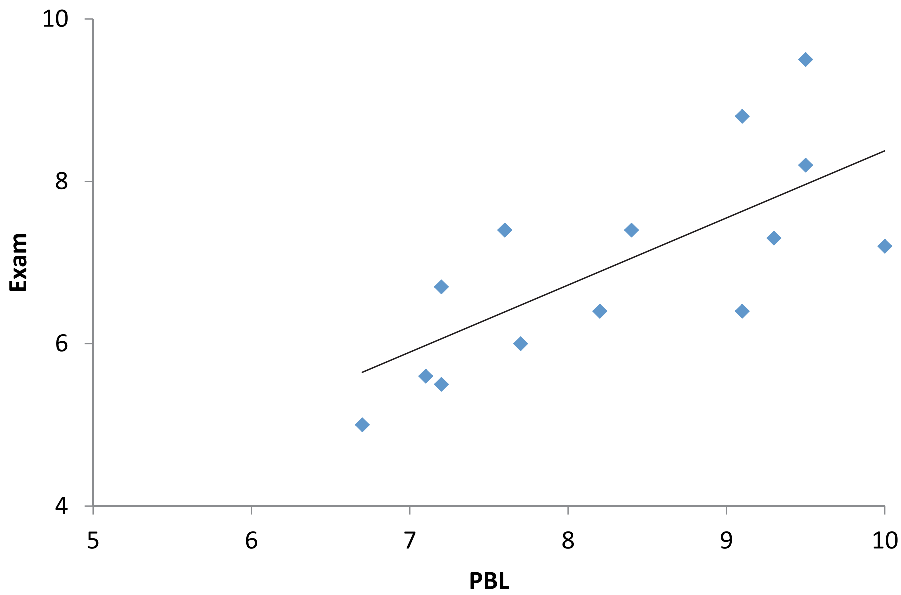

Figure 8. Evolution of the students' results in the exam versus results in PBL activity for the UB students

The results of the evaluation in the universities in which only part of the student participating in the PBL activity (i.e. UJI and UMA) showed that the success rate of the PBL students is higher than that of the students following the traditional methodology (non-PBL). Thus, in the UJI 90% of the PBL students passed the course in the first call, whereas only 45% of the non-PBL students succeed. In the case of the UMA, since weight of the PBL in the overall course grade was only 15%, the results were not as good as in the UJI. Nevertheless the same trend was observed: 44% of the PBL students passed the course in a first call, while only 27% of the non-PBL students succeed.

It is found that the specific knowledge gained through independent learning is solid and remains after the activity is finished. In the discussion and meetings that were held with students after the experience, the following perceptions were recorded: the students were very receptive and said it was an experience that allowed them to find their way. They noted that, initially, the transfer of responsibilities from the teacher to the students disturbed them, but as they proceeded with the project they developed more autonomous and more independent learning strategies. They agreed that, through the PBL, learning stayed longer. Unlike rote learning, this system provided them with greater retention over time. Despite the difficulties encountered with some members of their group, all participants recommend this method of learning to the rest of his classmates. The teachers, on their side, were satisfied with the experience, given the good results obtained; however, the project required an immense amount of work from the teachers and it was concluded that its organization should optimise instrument/evaluation criteria to make the evaluation more objective and less time consuming.

Discussion and meetings with the students also showed that task division in practice is difficult to implement. Even though students were allocated different rolls, in practice, all group members tended to do all tasks and specialising was difficult

Conclusions

A number of innovative methodologies are starting to be introduced into the university curriculum. In order to guarantee the success of these methodologies and to justify their introduction they need to be evaluated in a systematic manner. This evaluation allows the new methodology to be compared with traditional methodologies in a rigorous way and as accurately as possible in order to understand the advantages and disadvantages of each approach. Moreover such evaluation can further the understanding of the impact of applying such methodologies (Fernandez *et al.* 2006). The current work has contributed to the development of the practice of evaluation.

The results shown in this work strongly suggest that a PBL methodology greatly reinforces the learning cycle. This is in contrast to the current main stream approach where knowledge is delivered to the learner through non interactive lectures.

the In the groups observed in this work, PBL serves to increase student engagement and arouse interest in the material studied, which in turn helps them to understand their own knowledge of the course and perfect their skill set. Students are encouraged to become active members in their learning process and take responsibility for their own learning because their participation is essential in the PBL discussion. This provides them with an incentive to try to solve the projects proposed in the lecture room enabling students to deepen their understanding by framing their knowledge in a way that is meaningful to them. In addition, this approach facilitates the improvement of transversal skills and generates activities to practice these competencies and criteria for evaluating them. Specifically, the use of PBL has improved the student's ability to write technical documents, search for information and strengthened teamwork and presentation skills

Overall this experience has been very positive for lecturers and students alike. Some proposals for the future that we think should be considered are:

- To involve the students in evaluating their peers.
- To develop tools to facilitate efficient team working and thus reduce the workload of students and teachers.
- To improve the efficiency of the evaluation instruments
- For teachers to evaluate the PBL activity to improve the PBL process in subsequent years. Finally, we have demonstrated the feasibility of implementing the PBL methodology across different faculties and in distinct universities. It is the hope of the IdM@ti group that we continue to work with the PBL approach, furthering its development and impact in Material Science courses.

Acknowledgements

Authors wish to thank the Vicerrectorado de Estudiantes, Ocupación e Innovación Educativa from Universitat Jaume I de Castellón for the financial support throught the Project (PIE 2907/14). Additionally the authors thank the Vicerrectorado de Innovación Docente from Universidad del País Vasco.

References

Antepohl, W., Herzig, S. (1997) Problem-based learning supplementing the course of basic phamacology - results and perspectives from two medical schools.*Naunyn-Schmiedeberg's Archives of Pharmacology*, 355, R18.

Barbour, J. A. (2006) Team Building and Problem-Based Learning in the Leadership Classroom: Findings from a Two.Year Study.*Journal of Leadership Education*, 5(2), 28-40.

Barrows H.S. & Tamblyn R.M. (1980) Problem-Based Learning: An Approach to Medical Education. New York: Springer Publishing Company, p.1.

Barrows, H.S. (1986). A Taxonomy of problem-based learning methods. *Medical Education, 20(6), 481–486.*

Castells, M. (1996). La era de la información. Economía, sociedad y cultura. Vol. 1 México: Siglo XXI.

Delors, J. (Coord) (1996): La educación encierra un tesoro. Informe a la UNESCO de la Comisión Internacional sobre la educación para el siglo XXI. Madrid, Santillana.

Dueñas, V.H. (2001). El aprendizaje basado en problemas como enfoque pedagógico en educación para la salud. Colombia Médica, 32(4),1-8.

Dunlap, J.C. (2005). Changes in students' use of lifelong learning skills during a problem-based learning project. *Performance Improvement Quarterly, 18(1), 5-33.*

Fernández, M., García, J.N, de Caso, A., Redondo, F., Arias, O. (2006). El aprendizaje basado en problemas: revisión de estudios empíricos internacionales. *Revista de Educación*, 341, 397-418.

Jonassen, D. H., S.,Khanna K*., Implementing problem based learning in materials science*, Proceedings of the 2011 ASEE Annual Conference and Exposition, Vancouver, 2011.

Lesperance, M. M., *The effects of Problem Based Learning (PBL) on student's critical thinking skills*, PhD thesis, University of North Carolina at Greensboro, 2008.

Moust, J.H.C., Bouhuijs, P.A.J., Schmidt, H.G. (2007).El aprendizaje basado en proyectos: Guía del estudiante. Cuenca: Ediciones de la UCLM.

Papinczak, T., Young, L., Groves, M. y Haynes, M. (2007). An analysis of peer self and tutor assessment in problem-based learning tutorial. *Medical Teacher, 29(5), 122-132.*

Pozo, J.I. (2006). La nueva cultura del aprendizaje en la sociedad del conocimiento. In J.I Pozo; N. Scheuer; M. del P. Pérez; M. Mateos; E. Martín y M. de la Cruz. Nuevas formas de pensar la enseñanza y el aprendizaje. Barcelona: Graó.

Reeves, T Y Laffey, J. (1999). Design, assessment, and evaluation of a problem-based learning environment in undergraduate engineering.*HigherEducationResearch and Development,* 18(2), 219-232.

Santillán, F. (2006). El aprendizaje basado en problemas como propuesta educativa para las disciplinas económicas y sociales basadas en el B-Learning.Revista Iberoamericana de Educación, 40(2), 1-5.

Schaffer, S.P., Chen, X., Zhu, X., & Oakes, W.C. (2012).Self-efficacy for cross-disciplinary learning in project-based teams. Journal of Engineering Education, 101(1), 82-94.

Schmidt, H.G. (1983). Problem-based learning: rationale and description. *Medical Education, 17, 11-16.*

*Vizcarro, C. Y Juárez, E. (2009).¿Qué es y cómo funciona el aprendizaje basado en proyectos?. La metodología del Aprendizaje Basado en proyectos. Consultado en fecha 20/01/2015. htt*p://www.ub.edu/dikasteia/LIBRO_MURCIA.pdf

Zhang, F., Colmos, A., De Graaf,E.(2013) Conceptualizations on innovation competency in a problem- and project-based learning curriculum: From an activity theory perspective, *International Journal of Engineering Education,* 29, (1), 3-16.

Chapter 14

Computer based learning and comprehension of power generation cycles using a model programmed in Engineering Equation Solver (EES): Analysis of a Rankine and a Gas- Turbine Brayton cycles

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Abstract: The comprehension of the influence of each design and operation parameter in a power generation cycle requires a complex analysis mainly due to coupled effects existing in these cycles and which is too hard to be assessed manually by the students during a practical session. Therefore, the use of a software tool specially developed for this purpose becomes essential. The present work presents a model of a Rankine and a Gas-Turbine Brayton cycle developed in EES (Engineering Equation Solver), which enables the student to make simulations in the software and easily determine the optimal design parameters that would maximize the electric energy production in this kind of cycles. In order to evaluate the usefulness of this tool, two questionnaires with the same questions were prepared and were provided to the students before and after each of the practical sessions (one session dedicated to the Rankine cycle and the other one to the Gas-Turbine cycle). After analyzing the results of the questionnaires, and taking into account the comments provided by the students, it was concluded that using this methodology helps to stimulate the student's understanding during the session, and enables to verify that students put into practice their theoretical knowledge, being able to make a better transfer to more complicated and real applications in the future.

Keywords: Computer-aid learning and comprehension, engineering application, analysis and optimization of complex processes

Introduction

Context of the analysed subject

This paper presents a practical methodology to help the learning and comprehension of the students enrolled in a subject of the official master degree in "Energy Technology for a Sustainable Development" at the Universitat Politècnica de València (UPV) in Valencia, Spain. The master is divided in two main parts as shown in Figure 1: the first one comprises 4 compulsory fundamental subjects which cover 15 credits ECTS and the second, consists of 3 different specializations which cover the next 27 credits ECTS each. The subject that will be analysed in this paper is called 'Introduction to Energy Technology', and it is one of the fundamental subjects taught during the first semester of the master.

"Introduction to Energy Technology" is divided into two main parts: the first one covers an overview of the different energy sources, where their main technological aspects are studied; and the second one, covers the study of power generation cycles where not only the components are analysed but also the optimal design and operation parameters. Among the different practical lessons proposed, the ones that are trying to be improved with the descriptive work here presented is dedicated to analyse the Rankine and the Gas- Turbine Brayton cycles for power generation.

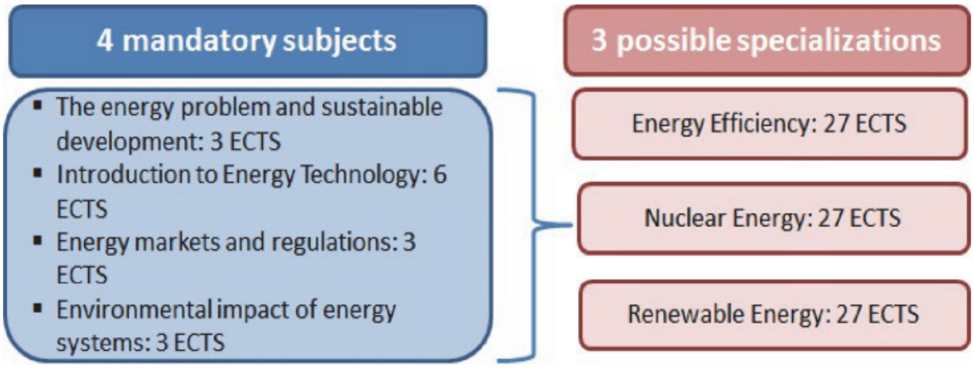


Figure 1. Structure of the "Master in Energy Technology for a Sustainable Development"

The subject has been taught by the authors for four years now, i.e, since the 2009-2010 academic year. Since then, a systematic observation was carried out and the feedback information collected by the students was reflected on a diary according to Zabalza (2004). Further analysis of this information allowed to have evidence of the students' opinion and thus enabled the authors to improve in their teaching-learning process, especially during the practical lessons of the subject. It was observed that, it was too hard and time consuming for students to manually analyse the influence of each of the design and performance parameters in a power generation cycle in a single practical lesson which turned out to be very time consuming and unfeasible in the duration of the subject. Therefore, it was considered the need of providing students with a software tool able to easily identify the main performance and design parameters of this kind of cycles, study its influence in the cycle's efficiency and learn to find their optimal values. This way, students could put into practice their theoretical knowledge by means of a software tool during the practical sessions of the subject.

Learning objectives and their importance in an engineering field

According to the operator of the Spanish electricity system, Red Eléctrica (2014), the 57.6% of the electric energy consumed during 2013 was produced using thermodynamic cycles. Nevertheless, the main energy source was the Eolic, covering the 21.1% of the demand, while the coal and the combined cycles descended their contributions to the 14.6% and 9.6% from the 19.3% and 14.1% reached in 2012.

This is just an example of the battle between the energy sources, which has been taking place during the last years, not only in Spain, but in other open-market systems all around the world. In this competition, the performance of the energy production plays a crucial role: manufacturers try to improve it so their energy source succeeds in producing the highest amount of energy at the lowest price.

In the fundamental operating cycles of thermodynamic plants, i.e. a Rankine cycle or a Gas- Turbine Brayton, there are a set of key factors which deeply influence their performance as it will be described in the following. The objective of the practical lessons here analysed is to identify these parameters, study its influence in each of the cycle's performance and learn to estimate their optimal values.

Computer based learning in engineering education

In the twentieth century, traditional lecture-based teaching processes have been criticized, as they have been defined as a passive knowledge delivery process that presents much room for improvement in the teaching-learning process.

Kozma (1987), identified computer tools as software programs that use the control capabilities of computers to amplify, extend, or enhance human cognition.

As it was pointed out in Egemen et al (1998), one of the fundamental prerequisites for improving the teaching-learning process of students consists in their active and interactive participation, both in and out of the classroom. In this context, computer simulation models were identified as an effective teaching aid to promote not only active participation between student and teacher but also among students. It was concluded that the use of such computer simulation models was attractive to students with different learning styles.

In Smit et al (1996), an experimental group of students, containing the students who followed computer-assisted learning was compared with another group that used traditional teaching techniques in Botswana. It was observed after the study, that the experimental group achieved significantly better results on the test than the traditional group. It was therefore concluded that the materials, specifically developed for computer-assisted learning, had a positive effect.

A similar approach was carried out by Cingi (2013), where the roles of computers in education were analyzed and a comparison of computer aided education versus traditional education was made. It was concluded that computer aided education eased the process of learning, as it was found that computer aided education students had better results in the course than traditional ones.

In Liu & Su (2011) a study was carried out for a high school in Taiwan in order to determine whether students using computer simulations learned better than traditional classroom learners in the domain of residential wiring. It was concluded that the students using computer simulations learned significantly better and reported higher cognitive load than did the traditional group.

In the field of engineering education, computers have become an essential tool especially in the visualization and solving of engineering problems. Şeker (2013) stresses out that computer training and computer assisted instruction should be expanded.

Hundhausen *et al.* (2011) demonstrated that a software environment that provides dynamically-generated feedback on the syntactic and semantic correctness of students' evolving disciplinary diagrams and mathematical equations could improve engineering students' problem-solving abilities.

Swart (2010) describes a method based on cooperative and computer-based learning for assisting senior engineering students to grasp fundamental communication principles related to single-sideband suppressed-carrier systems. After the session, the majority of polled students agreed that the practical work was very relevant to the theoretical instruction covered in the classroom. It was concluded that the students who were exposed to cooperative and computer-based learning were able to enhance their perception of engineering-related principles.

Kollöffel & De Jong (2013) developed an instructional approach in the form of inquiry learning in a virtual lab (based on simulation models in a computer) and demonstrated that it was more effective than relying on traditional instruction alone. Simulations contained models that were designed to simulate systems, processes, or phenomena. Students could change the values of the input variables in the simulation (e.g., the resistance in a virtual electrical circuit) and observe the effects that those changes produced in other variables (e.g., the voltage). In this context, computers can be identified as a very appropriate tool that can give feedback to students and help them analyze the reasons why their initial mental assignments were incorrect (Steinberg, 2000). It was concluded in the study that students in the virtual lab condition acquired better conceptual understanding and also developed better procedural skills than students in the traditional condition. Moreover, they showed a higher ability in solving complex problems.

The present paper presents the use of a software tool specifically developed to assist master students in the analysis and comprehension of Rankine and Gas-Turbine Brayton cycles during the practical sessions of a fundamental subject in the official master degree in "Energy Technology for a Sustainable Development" at the Universitat Politècnica de València (UPV) in Valencia, Spain. The paper will present the results obtained for this teaching technique of the Rankine and Gas-Turbine Brayton cycles which was recently carried out during the academic year 2013-2014. This same technique could be also applied to any other type of power generation cycle. The equations that describe the performance of the Rankine and Gas- Turbine Brayton cycles were programmed in a software tool that was previously described and provided to the students who learned how to use it. The model developed is very friendly to use, and it helps students to develop some other similar models in their future work. Therefore, it also contributes to the development of some of the competences related to the master: decision making, system design, research skills, applying knowledge to the industrial practice, or performing energy audit.

The usefulness of this tool is assessed by means of a descriptive study on teaching strategy developed in class. To this end, two questionnaires with the same questions are provided to the students: one before and another one after the practical session. Then, the student can compare the answers provided before and after the practical session and determine whether it has been useful to improve their understanding during the practical session and to a latter extent in their learning process. Nevertheless, as there are many other factors that could influence the student's performance, the authors are aware that, through the strategy employed, it cannot be ensured that this is the only factor affecting the achieved progress in the student's learning and comprehension.

No empirical data are presented by the authors in this work for two main reasons: first of all, the process will be repeated during the next academic courses in order to improve the software itself; and second, more information will be compiled by the authors over the next several years of teaching in order to have a greater amount of data and be able to make a more complete diagnosis.

Structure of the paper

First, as an introduction, the model of both the Rankine and the Gas- Turbine Brayton cycles developed is presented. A description of the ideal cycles is given, analyzing the inefficiencies that can be found and their effect, as well as the key parameters that play a role in the cycle efficiency. Second, the software tool developed is presented, showing an example of the parametric studies that can be performed using the model, in order to find the optimal values that enable to achieve the highest performance. Then, the work carried out in class is presented: a questionnaire to evaluate the initial knowledge of the student, a brief explanation of the software tool and its use, the analysis performed by the students, and the learning evaluation. The results obtained are analysed and discussed and, finally, the conclusions and future challenges are presented.

Rankine cycle: model developed

Description of an ideal Rankine cycle

The Rankine cycle is the fundamental operating cycle of all power plants where an operating fluid is continuously evaporated and condensed. The selection of the operating fluid mainly depends on the available temperature range, and it usually corresponds to water (steam). Figure 2a shows the components of a basic Rankine cycle: boiler, turbine, condenser, and circulation pump.

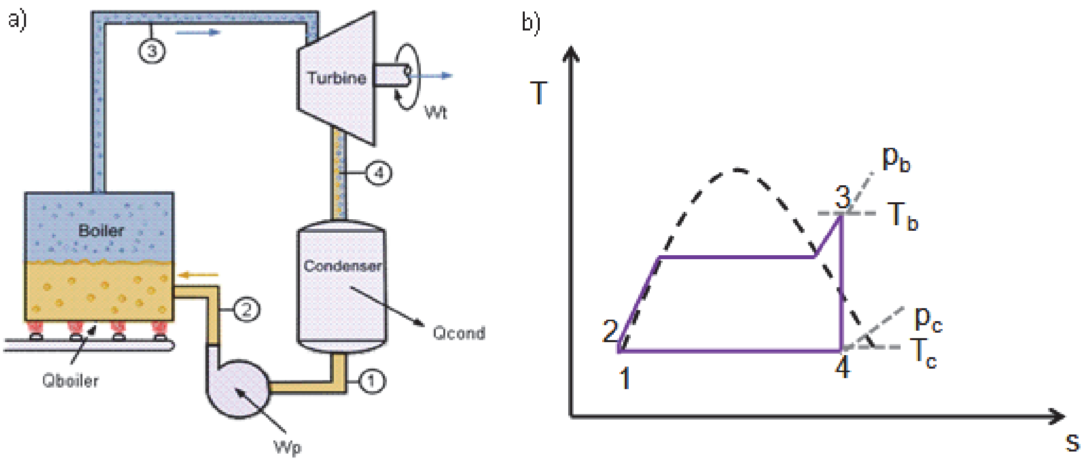


Figure 2. a) Rankine cycle: main components; b) T-s diagram of a Rankine cycle

There are four main processes that take place in a Rankine cycle, (Moran & Shapiro, (1999)):

1-2: Isentropic Compression. The fluid exiting the condenser (liquid state) is pumped from the pressure of the condenser, p_c, up to the pressure of the boiler, p_b. Due to the low specific volume of liquids, the pump work is relatively small and it is often neglected in thermodynamic calculations.

2-3: Isobaric Heat Transfer. The high pressure liquid enters the boiler from the circulation pump (2) and is heated up until reaching saturation conditions. In case of further energy addition, the evaporation of the liquid takes place until it is totally converted to saturated steam (3).

3-4: Isentropic Expansion. The vapour exiting the boiler is then expanded in the turbine, thus producing work which can be converted into electricity. The pressure of the exiting vapour from the turbine is limited by the temperature of the cooling medium in the condenser. On the other hand, in order to avoid the erosion of the turbine blades by liquid entrainment in the vapour stream during the last stages of the expansion process, the exit vapour qualities (x) are recommended to take values greater than 90%.

4-5: Isobaric Heat Rejection. The two phase flow (vapour-liquid) exiting the turbine (4) enters the condenser where the heat is rejected to a secondary fluid (cooling medium) which is usually water. In real systems, the pressure of the vapour takes values below the atmospheric pressure. The lower limit corresponds to the saturation pressure of the operating fluid in the cycle, calculated at the cooling water temperature conditions.

The efficiency of the power generation Rankine cycle is defined by equation (1):

$$\eta_{Rankine_{cycle}} = \frac{W_{net,Rankinecycle}}{W_p} \quad (1)$$

Where $W_{net,Rankinecycle} = W_{R_t} - W_p$, is the difference between the useful energy obtained in the turbine of the Rankine cycle, W_{R_t}, and the consumed energy needed in the circulation pump, W_p.

Inefficiencies of a Real Rankine Cycle

In real plants, each stage of the Rankine cycle is associated with irreversible processes, which reduce the overall efficiency. On one hand, turbine and pump present irreversibilities that reduce the overall efficiency of the cycle. The isentropic efficiency of the turbine and the pump is defined by equations (2) and (3) respectively.

$$\eta_{R_t} = \frac{W_{R_t}}{W_{R_{t,is}}} \quad (2)$$

$$\eta_p = \frac{W_{p,is}}{W_p} \quad (3)$$

where subscript 'is' indicates isentropic values.

Looking at equations (2) and (3), and taking into consideration that the efficiency takes values lower than 100%, it can be concluded that the irreversibilities make the real work obtained in the turbine decrease, and the real pumping work needed increase. The turbine efficiency directly reduces the work produced in the turbine and, therefore, the overall efficiency. The same thing happens with the pump efficiency: the work needed in the pump increases and reduces the overall efficiency. On the other hand, the heat transfer processes at the boiler and the condenser are not ideal and there exist associated irreversibilities, mainly because the heat transfer occurs across a temperature difference, causing the generation of entropy.

Increasing the Efficiency of Rankine Cycles: parameters of influence

The optimization of the cycles for power generation highly depends on the right choice of the design parameters. There are five main design and/or operation parameters that have an influence in the overall cycle efficiency:

- Inlet pressure of the operating fluid at the turbine (pressure at the boiler), p_b in Figure 2b: the higher the inlet pressure at the turbine, the higher will be the expansion work obtained.
- Inlet temperature of the operating fluid at the turbine, T_b in Figure 2b: the higher the inlet temperature at the turbine, the higher will be the expansion work obtained.
- Condensing pressure, pc in Figure 2b: the lower the condensing pressure (lower pressure at the outlet of the turbine), the higher the expansion work obtained. As the fluid exiting the condenser is set to be saturated liquid (x_1=0), the condensation temperature is not an independent parameter for the optimization process as it can be determined as the saturation temperature corresponding to the condensing pressure.
- Isentropic efficiency of the turbine: the higher it is, the greater the overall efficiency of the cycle would be.
- Isentropic efficiency of the circulation pump: the higher it is, the greater the overall efficiency of the cycle would be.

Gas- Turbine Brayton Cycle Model Developed

Description of an ideal Gas- Turbine Brayton cycle

The Gas- Turbine Brayton cycle is a thermodynamic cycle that describes the operation of a constant pressure heat engine. Gas turbine engines use the Brayton Cycle. Although the Brayton cycle is usually run as an open system (and indeed must be run as such if internal combustion is used), it is conventionally assumed for the purposes of thermodynamic analysis that the exhaust gases are reused in the intake, enabling analysis as a closed system (Closed Brayton cycle). Figure 3 shows the components of a basic Gas- Turbine Brayton cycle: a gas compressor, a burner (or combustion chamber) and a gas turbine.

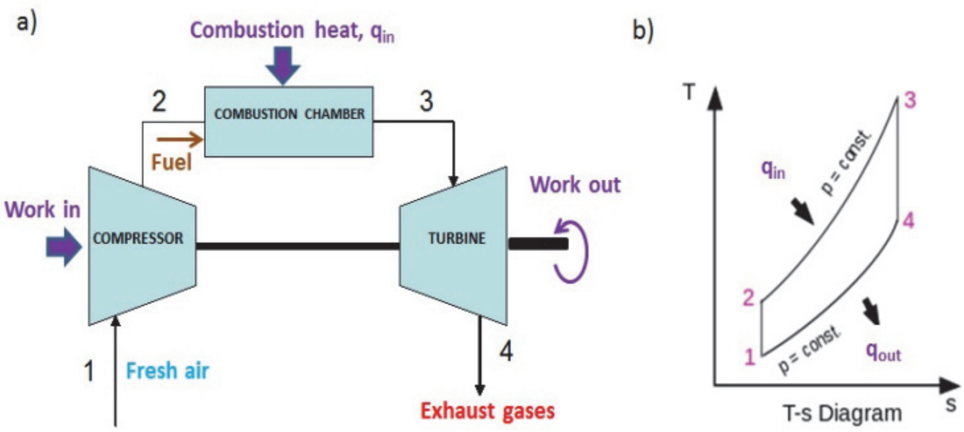


Figure 3. a) Gas- Turbine Brayton cycle: main components; b) T-s diagram of an ideal Gas- Turbine Brayton cycle

There are four main processes that take place in a Gas- Turbine Brayton cycle, (Moran & Shapiro (1999)):

1-2: Isentropic Compression. Ambient air is drawn into the compressor, where it is pressurized.

2-3: Isobaric Heat Transfer. The compressed air then is introduced in a combustion chamber, where fuel is burned, heating the compressed air at constant-pressure.

3-4: Isentropic Expansion. The heated and pressurized air enters the gas turbine (or series of turbines), and it expands obtaining useful energy. It should be stressed that some of the work extracted by the turbine is used to drive the compressor.

4-1: Isobaric Heat Rejection in the atmosphere. The exhaust gases in the gas turbine cool down at constant ambient pressure in contact with the atmosphere.

The efficiency of the power generation Gas- Turbine Brayton cycle is defined by equation (4):

$$\eta_{Brayton_{cycle}} = \frac{W_{net,Braytoncycle}}{W_c} \qquad (4)$$

Where $W_{net,Braytoncycle}$, is the difference between the useful energy obtained in the gas turbine W_{B_t}, and the consumed energy needed in the compressor, W_c.

Inefficiencies of Real Gas- Turbine Brayton Cycles

In real plants, each stage of the Gas- Turbine Brayton cycle is associated with irreversible processes, which reduce the overall efficiency. On one hand, turbine and compressor present irreversibilities that reduce the overall efficiency of the cycle. The isentropic efficiency of the turbine and the compressor is defined by equations (5) and (6) respectively, where subscript 'is' indicates isentropic values.

$$\eta_{B_t} = \frac{W_{B_t}}{W_{B_{t,is}}} \qquad (5)$$

$$\eta_c = \frac{W_{c,is}}{W_c} \qquad (6)$$

Looking at the formulas (5) and (6), and taking into consideration that the efficiency takes values lower than 100%, it can be concluded that the irreversibilities make the real work obtained in the turbine decrease, and the real compression work needed increase. The turbine efficiency directly reduces the work produced in the turbine and, therefore, the overall efficiency. The same thing happens with the compressor efficiency: the work needed in the compressor increases and reduces the overall efficiency. On the other hand, the heat transfer processes at the combustion chamber are not ideal and there exist associated irreversibilities. The heat combustion process will not be considered in the equations and the combustion chamber will be considered as a heat exchanger where the combustion heat is added to the compressed air at constant pressure.

For both the Rankine and the Gas-Turbine Brayton cycle, the calculation of heat and work per unit of mass of operating fluid can be expressed as the difference between the inlet and outlet enthalpy of the operating fluid at each component of the cycle.

Increasing the Efficiency of Gas- Turbine Brayton Cycles: parameters of influence

The optimization of the cycles for power generation highly depends on the right choice of the design parameters. There are four main design and/or operation parameters that have an influence in the overall cycle efficiency:

- Temperature of the air entering the turbine: the higher the inlet temperature at the turbine, the higher will be the expansion work obtained.
- Pressure ratio: relation between the inlet pressure at the turbine and the inlet pressure at the compressor (ambient pressure in open cycles). In principle, the greater the pressure ratio (greater inlet pressure at the turbine), the greater will be the efficiency of the cycle, but there is an optimum that will be analysed by the students in the practical session.
- Isentropic efficiency of the turbine: the higher the isentropic efficiency, the higher the efficiency of the cycle.
- Isentropic efficiency of the compressor: the higher it is, the greater is the cycle efficiency.

Methods

This section describes the steps and methodology that were followed during the teaching strategy followed in class.

Each practical session took place in a computer lab where 22 students were grouped in pairs, carrying out a cooperative work as proposed by Slavin (1990), and Reynolds *et al.* (2013).

The first practical session corresponded to the Rankine cycle, while the Gas-Turbine Brayton cycle was analysed in a second practical session.

First, a brief review of the theoretical knowledge needed to develop the tasks corresponding to the practical session was carried out. The equations needed to characterize the Rankine (first practical session) and the Gas- Turbine Brayton (second practical session) cycles which had already been presented during previous theoretical lessons, were reminded to students in order to make sure that they had the background needed to follow the practical session.

After this short review, the software tool was presented to the students, explaining them its main features and tools, and they were given some free time to get used to it.

An example of how to program the equations in the software was presented by the teacher and the students followed the steps needed to programme such equations, so that they were aware of the powerful of this tool that they could use in other similar subjects and even during their professional career by developing similar models to calculate other type of thermodynamic cycles or heat and mass transfer processes that take place in industrial applications.

Finally, a descriptive evaluation of the learning and comprehension of the students was carried out as presented in the following subsections.

Software tool developed in the Engineering Equation solver

As both the Rankine and Gas-Turbine Brayton cycles studied are closed cycles, there is a strong interdependency between the different design and operation parameters. Each of the states (1, 2, 3, and 4), previously presented in Figure 2 and Figure 3, are interdependent, which means that if one of them changes, the rest will be influenced and will also change. Thus, for each state, the thermodynamic properties need to be determined once again. Therefore, changing one design parameter implies that the student would need to redo all the calculations from the very beginning. Based on the teaching experience obtained in class, it normally takes the students forty minutes to solve a basic Rankine cycle and 30 minutes to solve a basic Gas-Turbine Brayton like the ones presented in Figure 2b and Figure 3b respectively.

As the duration of each practical session is two hours, it is unfeasible to make many parametric studies in order to find the optimal design and operation parameters for such cycles and have an overall view of the main effects. Hence, in order to better understand and check the influence of each of the design parameters presented above for each cycle, there is a need to use a software tool in which the necessary equations to calculate each state are already programmed. With the aid of this tool, the student would be able to easily check the effect of each parameter in the cycles' performance in a very fast way.

Engineering Equation Solver (EES: Engineering Equation Solver, 2015) was the software chosen to program the equations of the Rankine and Gas- Turbine Brayton cycle.

The EES is a general equation-solving program able to numerically solve a great number of coupled non-linear algebraic and differential equations. The main reason why it was chosen is the high accuracy of its thermodynamic and transport property database, available for hundreds of substances, which can be used with the equation solving capability. Among other features, the software allows carrying out parametric studies which are useful for optimization purposes.

This kind of software tools are especially important in real industrial applications, being used in power generation plants in which the thermodynamic cycle gets more complex including several expansion and regeneration processes.

It would take an engineer at least two hours to manually solve this type of cycle, making it totally inefficient to determine the optimal design parameters such as the intermediate pressures in the cycle, as it would mean many iterations of 2 hours each.

With the aid of software tools, several parametric studies can be carried out in order to calculate the value of the optimal design parameters at any cycle, and provide the results very fast by just clicking on a calculate button, independently of its complexity.

Figure 4 and Figure 5 present the interface that was developed in EES and provided to the student in order to analyse the influence of each design parameter on the performance of the Rankine and the Gas-Turbine Brayton cycle respectively.

Using this tool, the student can analyse the influence of each design parameter (which appear framed in Figure 4 and Figure 5 respectively) on the cycle efficiency, just by changing its value and clicking on the 'Calculate' button.

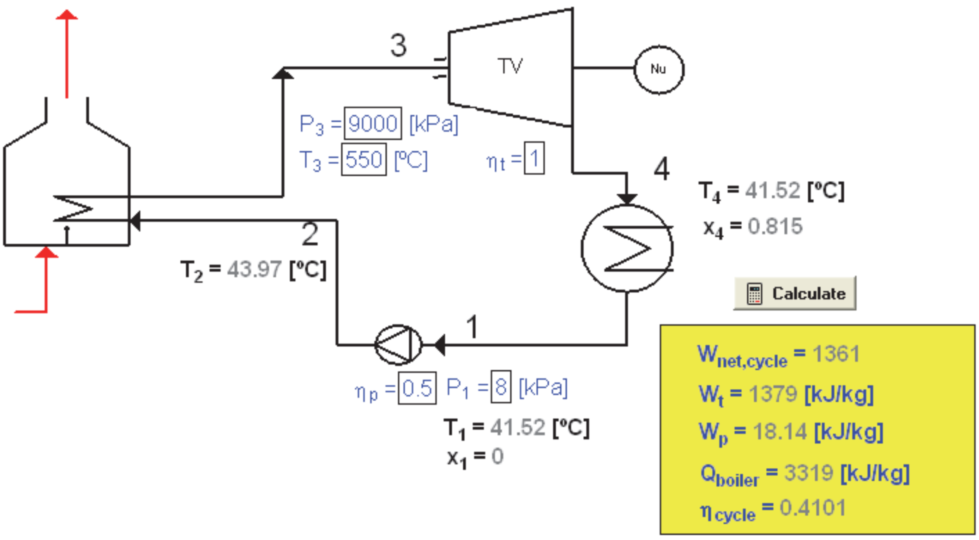


Figure 4. Basic Rankine cycle: diagram window programmed in EES

For instance, in the case of the Rankine cycle, they could determine the optimal inlet pressure at the turbine (P_3 in Figure 4) by making a parametric study, as shown in Figure 6a. Figure 6b shows another parametric study carried out by the students where they could analyse the influence of the condensation pressure (P_1 in Figure 4) in the efficiency of the cycle.

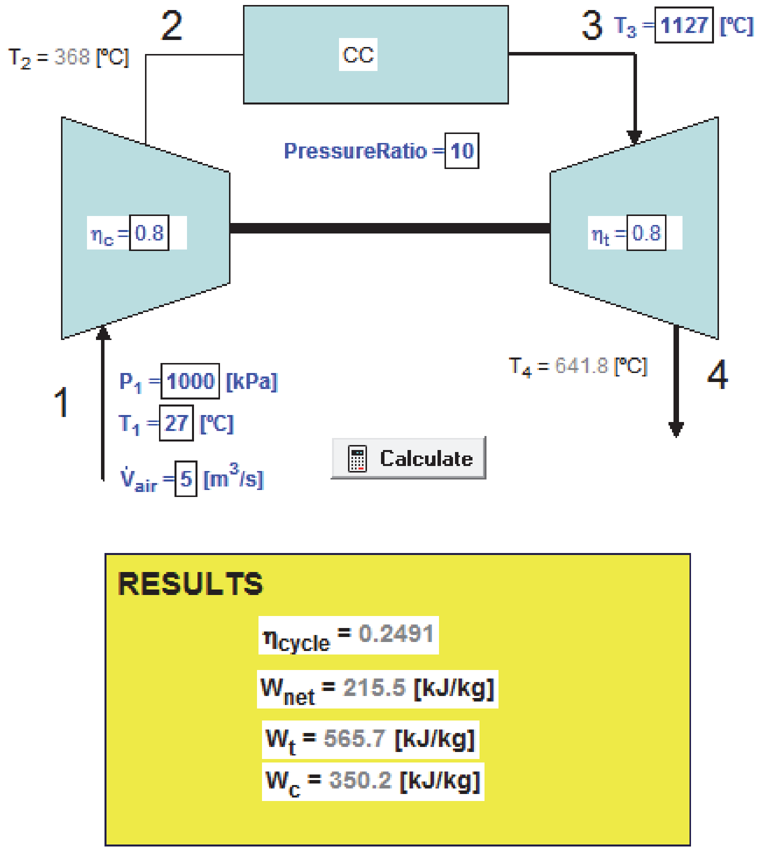


Figure 5. Basic Gas- Turbine Brayton cycle: diagram window programmed in EES

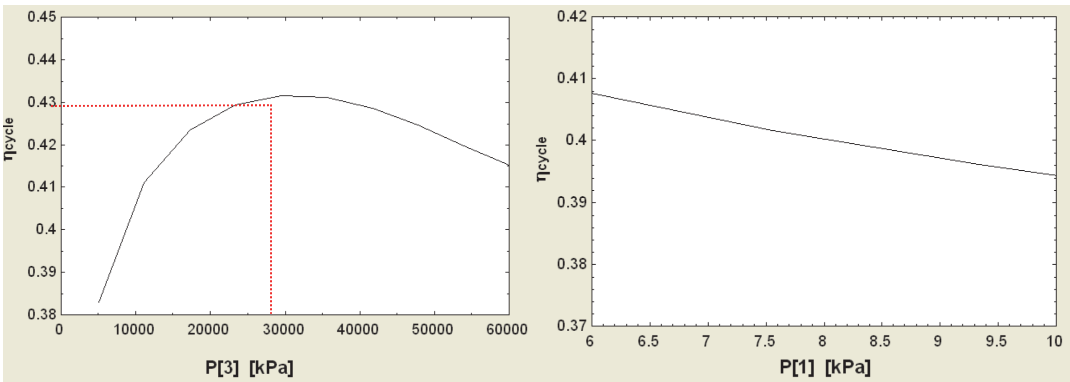


Figure 6. a) Influence of the turbine inlet pressure, P_3, in the cycle efficiency. b) Influence of the condensation pressure, P_1, in the cycle efficiency

Regarding the Gas-Turbine Brayton cycle, they could determine the optimal pressure ratio by making a parametric study, as shown in Figure 7a. Figure 7b shows another parametric study carried out by the students where they could analyse the influence of the temperature inlet of the air in the turbine (T_3 in Figure 5) in the efficiency of the cycle.

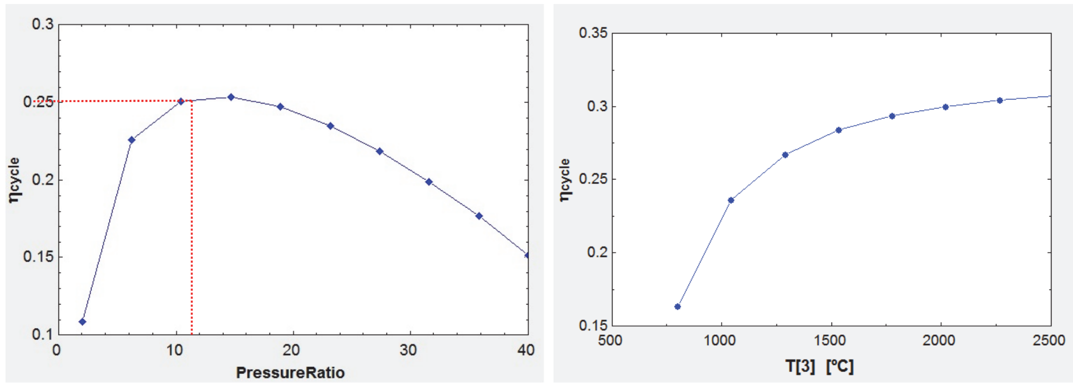


Figure 7. a) Influence of the pressure ratio in the cycle efficiency. b) Influence of the temperature of the air entering the turbine, T3, in the cycle efficiency

Evaluation of the learning and comprehension

Class work: questionnaires, brief explanation, analysis performed, and learning evaluation

In order to carry out a diagnostic evaluation of prior knowledge as explained in Gibbs (2003), a simple questionnaire was provided to each group (2 students) before starting the practical session.

The following questions were raised for the Rankine cycle:

- Which are the four main components of a basic Rankine cycle and which process does it take place in each of them?
- Which are the five main design parameters that have an influence on the efficiency of the cycle?
- How does the efficiency of the cycle vary when diminishing the value of each of the design parameters previously indicated in question number 2?
- Which is the parameter that has a greater influence on the efficiency of the cycle?

And these other questions, corresponding for the Gas- Turbine cycle:

- Which are the three main components of a basic Gas- Turbine Brayton cycle and which process does it take place in each of them?
- Which are the four main design parameters that have an influence on the efficiency of the cycle?
- How does the efficiency of the cycle vary when diminishing the value of each of the design parameters?
- Which is the main parameter that has a greater influence on the efficiency of the cycle?

Once the students had filled in the questionnaires, a brief theoretical review was carried out and the software tool was presented to the students so that they could program the equations of the cycle. Among the main features of the EES software, extra time was dedicated to the use of the parametric studies tool and the diagram window previously presented in Figure 4 and Figure 5. Figure 8 presents the equations that were programmed by the students in the software for the Rankine cycle. The same was done for the Gas-Turbine Brayton cycle.

INPUTS

Temperature & Pressure conditions at the inlet of the turbine

CALCULATIONS

Equations of the basic Rankine cycle

Note: heat and work are expressed as a function of the mass of operating fluid

$P_1 = P_4$

$P_2 = P_3$

$x_1 = 0$ the exit of the condenser is set as saturated liquid

$h_1 = \mathbf{h}(Steam, x=x_1, P=P_1)$

$v_1 = \mathbf{v}(Steam, x=x_1, P=P_1)$

$T_1 = \mathbf{T}(Steam, x=x_1, P=P_1)$

$W_{p,is} = v_1 \cdot (P_2 - P_1)$ isentropic pumping work needed

$\eta_p = \frac{W_{p,is}}{W_p}$ isentropic efficiency of the circulation pump

$W_p = h_2 - h_1$ real pumping work

$T_2 = \mathbf{T}(Steam, P=P_2, h=h_2)$

$s_2 = \mathbf{s}(Steam, P=P_2, h=h_2)$

calculation of state 3, at the entrance of the turbine

$h_3 = \mathbf{h}(Steam, T=T_3, P=P_3)$

$s_3 = \mathbf{s}(Steam, P=P_3, T=T_3)$

OUTPUTS

Performance parameters

$W_{net,cycle} = W_t - W_p$

$Q_{boiler} = h_3 - h_2$

$\eta_{cycle} = \frac{W_{net,cycle}}{Q_{boiler}}$ cycle efficiency

Figure 8.Equations programmed by the students in the EES software tool. Example: Rankine cycle

After introducing the equations of the cycle in the EES software, students were asked to carry out several parametric studies (like the ones previously presented in Figure 6 and Figure 7 in order to analyse the influence in the cycle efficiency of the main parameters for each cycle. Rankine cycle: inlet pressure of the operating fluid at the turbine (P_3); inlet temperature of the operating fluid at the turbine, (T_3); condensing pressure, (P_4); isentropic efficiency of the turbine, η_{Rt}, and isentropic efficiency of the circulation pump, η_p. Gas-Turbine Brayton cycle: inlet pressure of the air at the turbine (P_3), which varies modifying the value of the pressure ratio; inlet temperature of the air at the turbine, (T_3); isentropic efficiency of the turbine, η_{Bt}, and isentropic efficiency of the compressor, η_c. Finally, the same questionnaire was provided to the students who were asked to answer exactly the same questions that were raised at the beginning of the practical session.

Results and Discussion

The correct answers to each question raised in the diagnostic evaluation of prior knowledge are presented in the following for the Rankine and the Gas-Turbine Brayton cycle respectively.

Rankine cycle:

1. Which are the four main components of a basic Rankine cycle and which process does it take place in each of them?

- Boiler: Isobaric Heat Transfer
- Turbine: Isentropic Expansion.
- Condenser: Isobaric Heat Rejection.
- Circulation pump: Isentropic Compression

2. Which are the five main design parameters that have an influence on the efficiency of the cycle?
    - Inlet pressure of the operating fluid at the turbine (P_3)
    - Inlet temperature of the operating fluid at the turbine, (T_3)
    - Condensing pressure, (P_4)
    - Isentropic efficiency of the turbine, η_{Rt}
    - Isentropic efficiency of the circulation pump, η_p.
3. How does the efficiency of the cycle vary when diminishing the value of each of the design parameters previously indicated in question number 2?
    - The efficiency of the cycle decreases
    - The efficiency of the cycle decreases
    - The efficiency of the cycle increases
    - The efficiency of the cycle highly decreases
    - The efficiency of the cycle is barely influenced, presenting a very little decrease.
4. Which is the parameter that has a greater influence on the efficiency of the cycle?
    - Isentropic efficiency of the turbine, η_{Rt}

Brayton cycle:

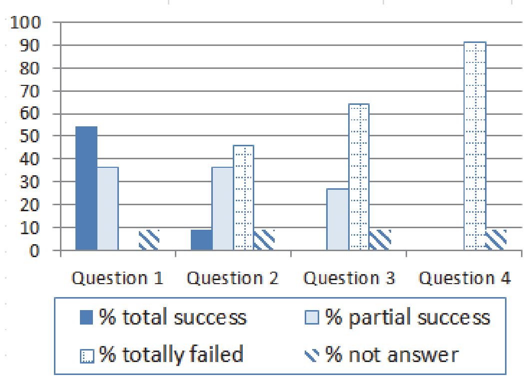
1. Which are the three main components of a basic Gas- Turbine Brayton cycle and which process does it take place in each of them?
    - Combustion Chamber: Isobaric Heat Transfer
    - Turbine: Isentropic Expansion.
    - Compressor: Isentropic Compression
2. Which are the four main design parameters that have an influence on the efficiency of the cycle?
    - Inlet temperature of the operating fluid at the compressor, (T_1)
    - Inlet temperature of the operating fluid at the turbine, (T_3)
    - Pressure ratio
    - Isentropic efficiency of the turbine, η_{Bt}
    - Isentropic efficiency of the compressor, η_c.
3. How does the efficiency of the cycle vary when diminishing the value of each of the design parameters?
    - The efficiency of the cycle slightly increases
    - The efficiency of the cycle increases

- The efficiency of the cycle decreases
- The efficiency of the cycle highly decreases
- The efficiency of the cycle highly decreases but it has a lower influence than in the case of the isentropic efficiency of the turbine

4. Which is the parameter that has a greater influence on the efficiency of the cycle?
    - Isentropic efficiency of the turbine, η_{Bt}

Figure 9 and Figure 10 present the results obtained in the pre-test and post-test for the Rankine and the Gas-Turbine Brayton cycle respectively. Results are expressed as the percentage of students that successfully answered to each question, those that partially succeeded in their answer, those that totally failed, and finally, those that left it blank notes.

In general terms, Figure 9a and Figure 10a show that approximately half of students knew the correct answer to the first question for both cycles, since it is the most basic one, and it can be answered from the theoretical knowledge taught in several classes prior to the practical session. However, as the difficulty of the questions increases (question 2, 3 and 4) due to the greater involvement of reasoning ability in which it is necessary to consider the influence of the different parameters in the design and operation of both cycles, the percentage of students who knew the correct answer decreases drastically to reach values lower than 10% and even reaching values of 0% for questions 3 and 4, with a small percentage of 15% to 20% of students that partially answered correctly to questions 2 and 3. On the other hand, it can also be observed that a high percentage of students just left it blank notes, probably for fear of being judged by providing a wrong answer. In this case, the percentage of students not providing an answer was around 9% for the Rankine cycle, while in the case of the Gas-Turbine Brayton cycle the percentage was even higher getting values higher than 20% or even 45% in question 3.



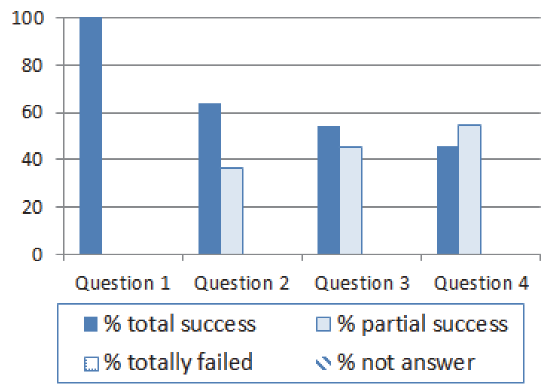


Figure 9. a) Results obtained in the pre-test for the Rankine cycle. b) Results obtained in the post-test for the Rankine cycle

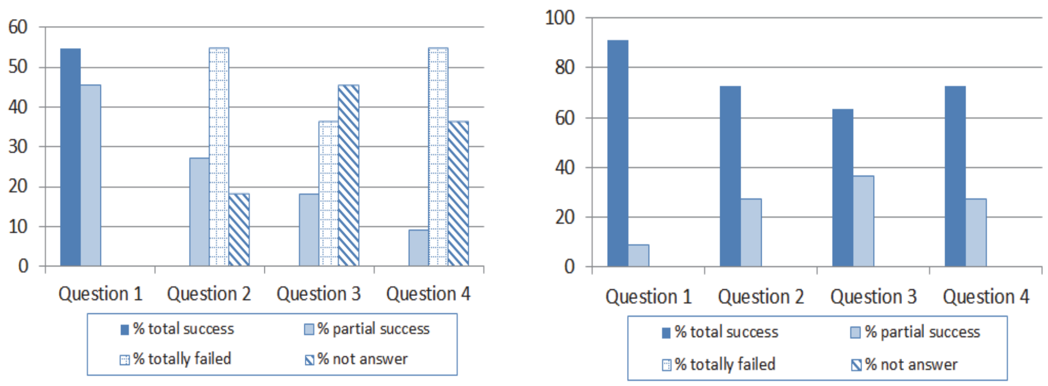


Figure 10. a) Results obtained in the pre-test for the Gas-Turbine Brayton cycle. b) Results obtained in the post-test for the Gas-Turbine Brayton cycle

Figure 9b and 10b shows the results obtained after each practical session. As it can be observed, almost 100% of students correctly answered the first question, being the percentage a bit lower around 90%) in the case of the Gas-Turbine Brayton. With respect to the second question, the percentage of students who answered correctly highly increased in comparison with the pre-test results, being the percentage of students that totally succeeded around 60% in the case of the Rankine cycle and 70% in the case of the Gas-Turbine Brayton cycle. The same happened in questions 3 and 4, in which the success rates clearly increased from 0% in the pre-test to 38% and 30 % in the post –test respectively in the case of the Gas-Turbine Brayton cycle; whereas in the case of the Rankine cycle, the percentage of success are even higher, getting approximate values of 65% and 70% respectively. It is observed that the percentage of students that totally failed the questions or those who left it blank notes has decreased considerably taking values of 0% for both types of cycle. Finally, taking a look at the results, it can be concluded that the practical sessions were useful for students who, after each practical session, had acquired a better comprehension of how the Rankine and the Gas- Turbine Brayton cycle perform as well as the influence of each of the design parameters on the efficiency of both cycles. So, results are consistent with other similar experiences where computer assisted learning was considered such as in Swart (2010), Liu & Su (2011), Hundhausen *et al*., (2011), and Kollöffel & De Jong (2013).

Conclusions

Based on the results observed in this descriptive study and considering the feedback provided by the students after the practical sessions, it was concluded that the developed tool and methodology followed helped to ease the student's comprehension during the session, making it possible to verify that it may have contributed to an improvement and stimulation in their personal learning process. Early feedback from students was very positive, as some of them informed the authors that they used it to prepare the exam, and confirmed their willing to use it in future works. On the other hand, it has been used in other lectures of the master, providing it with a multidisciplinary approach.

In order to allow a more complete analysis, the following future actions are proposed:

- Perform a qualitative analysis of the data through the development of surveys in which the students express their opinion on the usefulness of the methodology presented.

- Repeat the process along different academic courses, and take into account the feedback from students to improve both the software and the teaching strategy followed.
- Follow up with some students during their early working life and check whether they use it or they would find it useful at their work.

References

Cingi, C.C. (2013). Computer aided education. *13th International Educational Technology Conference. Procedia - Social and Behavioral Sciences*, 103, 220-229.

Egemen, E., Edwards F., Nirmalakhandan N. (1998). Computer simulation models in environmental engineering education. Water Science and Technology, 38 (11), 295-302.

Kollöffel, B. & De Jong, T. (2013). Conceptual Understanding of Electrical Circuits in Secondary Vocational Engineering Education: Combining Traditional Instruction with Inquiry Learning in a Virtual Lab. Journal of Engineering Education, 102(3), 375-393.

Kozma, R.B, (1987). The Implications of Cognitive Psychology for Computer-Based Learning Tools. Educational Technology, 27 (11), 20-25.

Liu, H.C & Su, I.H. (2011). Learning residential electrical wiring through computer simulation: The impact of computer-based learning environments on student achievement and cognitive load. *British Journal of Educational Technology,* 42(4), 598-607.

Red Eléctrica de España. El sistema eléctrico español: Avance del informe 2013, Retrieved January 21, 2014, from http://www.ree.es/sites/default/files/downloadable/avance_informe_sistema_electrico_2013.pdf

Reynolds, W., Miller, G. & Weiner, I. (Eds.) (2013). Cooperative Learning and Achievement: Theory and Research. Handbook of Psychology (2nd ed., Vol.7, pp. 199-212). Hoboken, NJ: Wiley.

Şeker, S. (2013). Computer - Aided Learning in Engineering Education. *2nd World Conference on Educational Technology Researches – WCETR2012. Procedia - Social and Behavioral Sciences*, 83, 739-742.

Smit, C. P., Oosterhout, M., Wolff, P. F. J. (1996). Remedial Classroom teaching and computer-assisted learning with science students in Botswana. *Int. J. Educational Development*,16 (2), 147-156.

Steinberg, R. N. (2000). Computers in teaching science: To simulate or not to simulate? *American Journal of Physics*, 68, 37-41.

Swart A.J. (2010). Enhancing Students' Perception of Single-Sideband Suppressed-Carrier Principles by Using Cooperative and Computer-Based Learning. *Computer Applications in Engineering Education* , 20(2), 332-338.

Zabalza, M. Á. (2004). Diarios de clase: un instrumento de investigación y desarrollo profesional, Madrid: Narcea.

Chapter 15

Motivating Computer Engineering Students to the application of legal issues: a professional approach

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Abstract: Nowadays, new business models are arising thanks to the development of ICT. In this context, the law is constantly being adapted to guarantee rights of individuals. Studying topics related to legislation generally does not motivate computer students, especially if it is done in a theoretical way or if examples used in practical lessons are simple. In addition, according to the *Instituto Nacional de Tecnologías de la Comunicación*, a high percentage of Small and Medium Enterprises does not consider current legislation on issues related to ICT. So, we decided to engage computer students of the need to respect regulations for the development of any software project by the practical use and respect of these laws, by applying practical tasks of an Information Systems course on an active computer research project. Results were really positive. Mainly, students increased their knowledge of Information Systems, especially their expertise and know how; they did it in a more entertaining way; and they were more aware of the need to accomplish with legal issues than in previous courses. In conclusion, students really changed their mind: they were motivated to consider legal issues on their applications, and claimed that they would like to learn more about them.

Keywords: project based learning; problem based learning; professional approach; active learning

Introduction

During the last decades there has been a huge increase in the amount of digitized data available to be processed, thanks to the development of Information and Communication Technology (ICT). This has led to new business models and applications in many areas and sectors. In particular, in the health scope has emerged the area of bioinformatics. According to the definition available in *Wikipedia* (accessed on September the 29th 2015), bioinformatics is an interdisciplinary field that develops methods and software tools for understanding biological data. Furthermore, in recent years, there has been an increase in Small and Medium Enterprises (SMEs), and emerging research groups that thanks to the popularization of biomedical sensors, develop management and processing systems of biomedical signals (signals originated by the human body, used in diagnosis or medical research) with different objectives: improving cognitive development (Escolano, Navarro-Gil, Garcia-Campayo & Mínguez, 2013), determining the level of stress (Dranca *et al.*, 2013), developing of neuromarketing applications (Javor, Koller, Lee, Chamberlain & Ransmayr, 2013), increasing diver safety, (Izquierdo *et al.*, 2015), etc.

At the same time, the development of ICT has generated the need to create and adapt legislation in order to guarantee people rights and duties in the context of the so-called Information Society. Some concrete examples in the Spanish scope are the *Ley Orgánica 15/1999, de 13 de diciembre, de Protección de Datos de Carácter Personal* (LOPD; Personal Data Protection) and the *Real Decreto 1720/2007, de 21 de diciembre, de aprobación del Reglamento de desarrollo de la LOPD* (RLOPD; regulations implementing the LOPD). However, according to data provided by the *Instituto Nacional de Tecnologías de la Comunicación* (INTECO; National Institute for Communication Technologies)[10], a high percentage of SMEs are not aware of being subjected to these laws (Pérez San-José, Gutiérrez Borge, Álvarez Alonso & García Pérez, 2012), despite of the work that some institutions such as the *Agencia Española de Protección de Datos* (AEPD; Spanish Agency for Data Protection) have already done.

Bioinformatics Research Project

In this context, we decided to tackle the challenge of the development of an information system to manage data and information from a research project in which we were participating, and to describe lessons learned during its development. Concretely, the research project used in the experience related here is CUD2013-11 (Peláez Coca, 2014), originally called: Identificación de Situaciones de Disminución del Rendimiento del Militar, basado en la Relación de la Variabilidad del Ritmo Cardiaco con el estrés y la Privación de sueño; in English: Identifying Situations where Military personnel Performance is Decreased, based on the relationship of Heart Rate Variability with Stress and Sleep Deprivation.

This is a research project developed at the Centro Universitario de la Defensa de Zaragoza, where a big amount of biological and also personal data is managed (registered, maintained, etc.). The ultimate goal of this project is to develop an automatic identifier of the operating performance of security and defence personnel from biomedical signals for carrying out activities with great physical and/or cognitive requirements. To this end, different multimodal biosignals are registered in several experimental subjects, while they face a highly stressful task with great cognitive requirements.

Briefly, mental fatigue and stress are considered, as these two variables affect performance in cognitive tasks of high attention requirements. On the one hand, regarding evaluation of mental fatigue, the electroencephalogram (EEG) signal is considered a physiological reference standard. On the other hand, the analysis of the electrocardiogram (EEG) signal and the muscle electrical activity, is really interesting as it is related to both types of fatigue: mental and physiological.

As stress is often associated with increased sympathetic control/decreased parasympathetic control, it is measurable through the analysis of the heart rate variability (HRV). At the same time, the electrical activity of the skin is one of the most used psychophysiological indexes as physio-psychological correlation (Aiger *et al.*, 2014).

[10] Notice that currently INTECO is called *Instituto Nacional de Ciberseguridad* (INCIBE; National Institute for Cibersecurity). This change of name was done on 28th October 2014.

The importance of the data collected in this research project and the relevance of its safety (for both, project development and even more, for privacy of experimental subjects) is trully high, as they are not *only* personal data, but also biomedical, which is really sensible data. In the framework of storage and maintenance of this data, we developed a series of guides defining behaviour protocols, where the convenience of the application of safety politics from the first draft, much time before the collection of data have been worth (Lozano & Trillo-Lado, 2014). So, we thought that this was the best environment to learn the importance of applying the normative and legal framework, and to do it from the beginning of an information system project: the information system development for the above mentioned research project (Peláez Coca, 2014).

In order to develop this experience with students, we applied for a proyecto de innovación (teaching innovation project) to the Universidad de Zaragoza that was selected for its development. We called it Acercamiento a la realidad profesional: desde un proyecto informático a la asignatura Sistemas de Información (Lozano, 2014; in English: A professional approach: from a computers project to the subject Information Systems).

Normative and Legal Framework

Starting from this environment, the objective of this work was that the students of the Degree in Computer Engineering would live an experience where they develop an application similar to the ones that they are supposed to find in their professional career when they would finish their universitary education. Thus, in this context, they have been responsible of specific tasks to be performed within a technological innovation project that is already being developed, with the aim of motivating them in the study of existing legislation on issues related to ICT and Information Systems. Moreover, they also learnt about norms by applying them.

Extracted from the professional reality, the activities were introduced in different sessions of problems and practices (see Annex I and Annex II) in the Information Systems course, with the main objective of helping students to better assume the concepts, the techniques and the technologies used to develop an information system, while involving students of the need to respect the regulations and norms for the development of any software project or information system in general. Moreover, special emphasis was done explaining the concept *normalization*. Normalization is the process of developing, implementing and improving the rules that apply to different scientific, industrial or economic activities in order to arrange and improve them. Broadly, the normalization essentially pursues these three objectives:

1. simplification: to reduce the number of models to work with and to keep only the more necessary information;
2. unification: to allow international exchange of different methods, concepts and tools;
3. specification: to avoid errors in identification and interpretation, creating a clear and precise language;

Thus, for the aspects of analysis, design, development, implementation and maintenance of the information system to support CUD2013-11 project (Peláez Coca, 2014), we have taken into account the guidelines of the *Asociación Española de*

Normalización y Certificación (AENOR; Spanish Asociation for Normalization and Certification) and the standards established by the International Standard Organization (ISO) for the government and the administration of the technologies and information systems. Furthermore, as shown in the different guidelines and standards, we have considered the study of current legislation. So, it was shown to the students in this way.

In the work we present here, we firstly studied the family of ISO standards 20000 and 27000 (see Figure 1), considering them more relevant than others when starting the development of hardware and software infrastructure to support the information systems required.

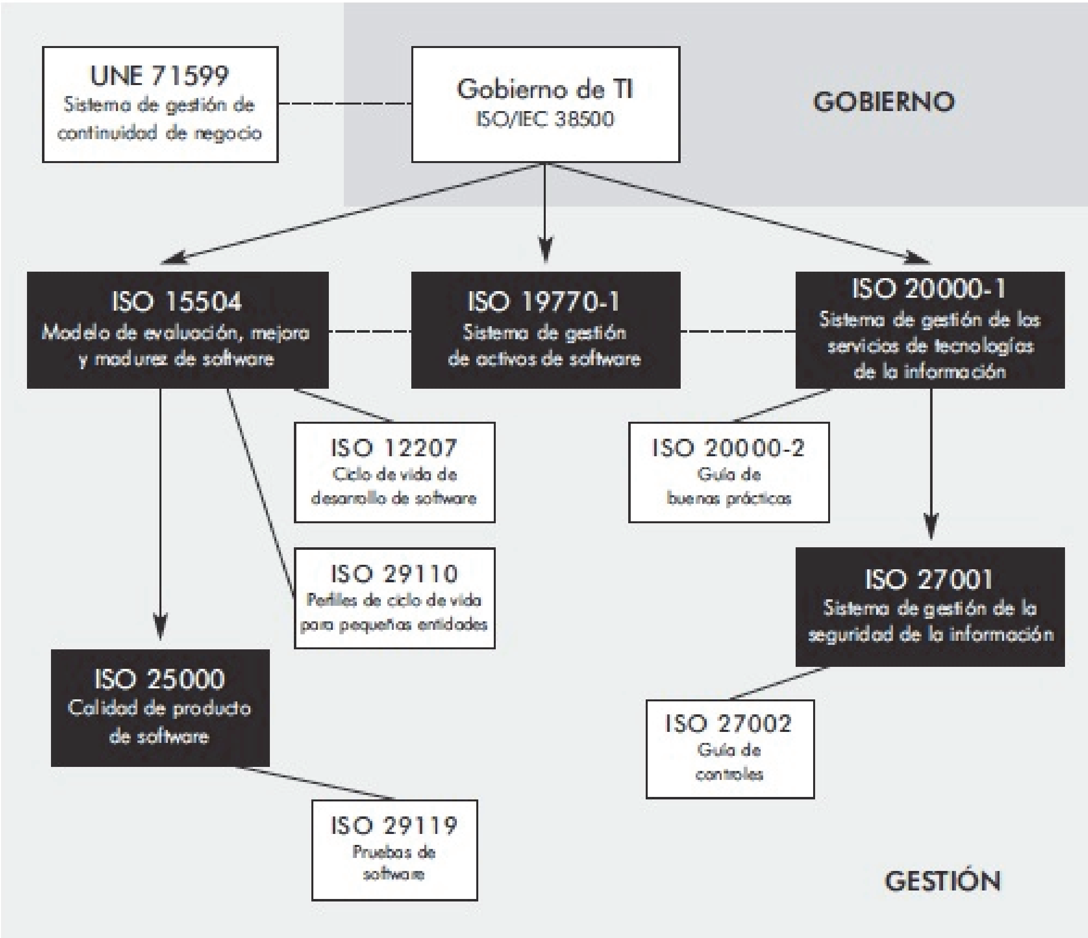

Figure 1. Expanded AENOR model for ICT. Source: Fernándes Sánchez and Piattini Velthius (2012)

The ISO 20000 series deals with aspects related to the management of ICT services and is based on an oriented process to provide users with services that meet the requirements established and a continuous improvement through the PDCA (Plan, Do, Check, Act) model (see Figure 2).

The ISO 27000 series focuses on information security, that is, the preservation of the confidentiality, integrity and availability of data and information. Security information can also include other properties such as authenticity (assurance that an entity is who it is said to be or that an entity guarantees the source from which the data comes from) and traceability (ensuring that at any time it will be able to determine who did what and when).

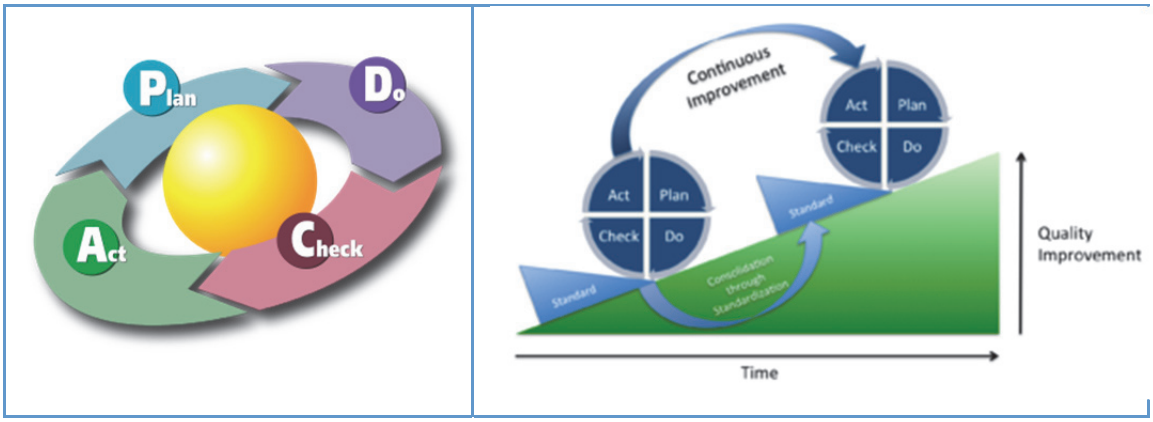

Figure 2. a) Representation of the PDCA model. b) Continuous quality improvement with PDCA. Source: https://en.wikipedia.org/wiki/PDCA (accessed on September, 24th 2015)

Regarding the legislation, the main aspects of the legal framework on the Information Society were considered in relation to the management of safety systems and technologies of information (see Figure 3). Specifically, we initially focused in the study and analysis of the LOPD and RLOPD. In addition, the current regulations proposal related to data protection in the European Union (EU), European Union (2012) has been taken into account.

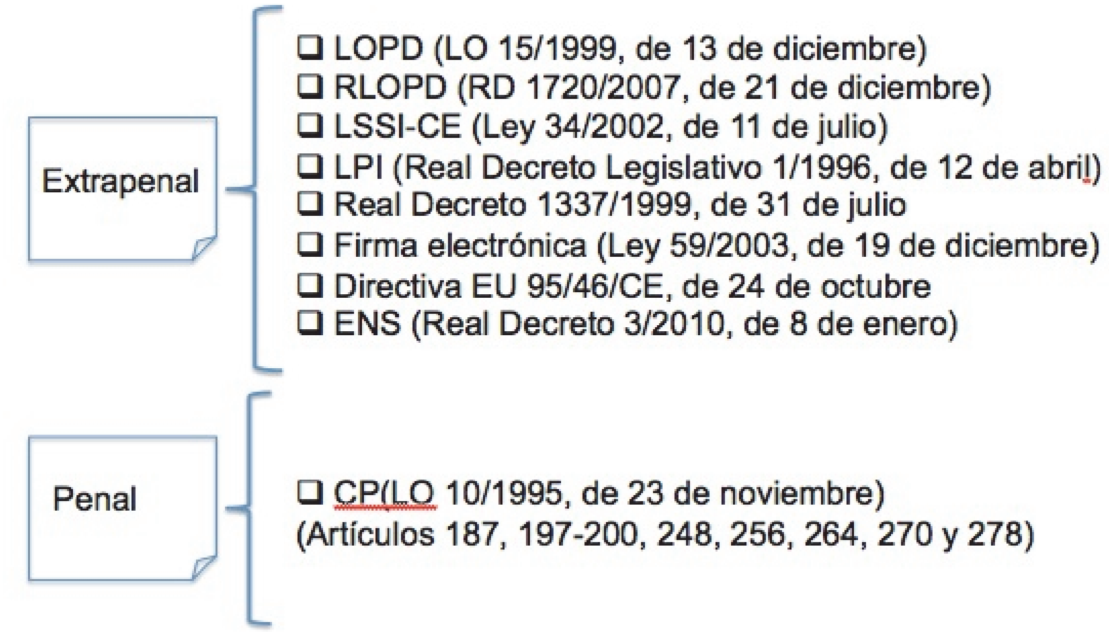

Figure 3. Existing legislation related to Information Systems. Source: Lozano and Trillo-Lado (2014)

Methodology

The target audience of this experience of professional approach are the students of the Information Systems course. This course belongs to the Degree in Computer Engineering taught at the *Escuela de Ingeniería y Arquitectura,* Universidad de Zaragoza. In general, during the development of practices and problems of the course, students often work with simple examples that do not motivate them. Besides, aspects of legislation in the field of ICT in a Degree in Computer Engineering or Computer Science do not usually appeal to students. Therefore, in this paper we propose that students work and develop their practice inside a research project that was already being developed.

As a reminder, the chosen project was one in charge of sensitive data, in wich we were participating. The project was in charge of identifying among several situations, specialy those in which the subject is affected by a decrase in the performance. It was focused on registering some biomedical signals of the experimental subjects, in order to stablish a relation between HRV and stress and sleep deprivation (Peláez Coca, 2014). In case more information is needed, refer to section *Research Project*.

So, in this project, the need of storage of so sensitive data demands an information system useful to store and maintain data completely safe. That is to say, safe from:

1. own mistakes of the system and
2. possible outsider attacks.

The main innovation introduced by this paper is, therefore, the use of a real development and technological innovation project, in order to motivate students to study existing legislation and norms on issues related to ICT and Information Systems (Project Based Learning, PBL). Activities are introduced in different kinds of problems and practices (see Annex I and Annex II) of the subject involved.

With these activities is intended to get students close to professional reality in relation to the subject. The main objective, consequently, is that this professional experience could help students to better assume the concepts, the techniques, and the technologies used for the development of an information system, from the knowledge and fulfilment of the law, principally, and also the norms. In order to accomplish these objectives, we focus on the *know how* point of view, affording them a practical and real approach. At the same time, this approach results more motivating to them, and helps to understand the necessity of being so careful in relation to normative and legal issues.

It is important that students understand that no set of standards, methodologies and laws can guarantee the full success of the development, implementation and maintenance of an information system. However, the most important point is that they realise that considering national and international standards and norms, and the use of standard methodologies, they:

1. facilitate the management of the project (the system does not depend only on the point of view of a particular person),
2. save time (no need to reinvent something already used by others) and
3. facilitate communication among different team members.

Apart from the fulfilment of the law, one of the main ideas to be conveyed to students is that it is necessary to consider the safety aspects of the storage, processing and transmission of data and information from the beginning of the project; and not only when implementing and parameterizing the specific software.

For the development of this experience, the following main activities have been planned:

1. initial development and approach to the foundations of the computer project to be approached;

2. based on the previous expertise, designing and setting of the practices (see Annex I and Annex II) and problems to be solved in the classroom, in relation to the various tasks to be performed on the computer project (Problem Based Learning and Project Based Learning);
3. estimating of the workload of the practices assessment proposed to students;
4. development of the practice and problems sessions;
5. evaluating the development of the practices and the final result of them;
6. satisfaction survey designing and evaluation of the activity, to be completed by students;
7. designing of the interviews to be conducted to students of current and previous year;
8. a final evaluation of the experience, so that the strengths and weaknesses of it are obtained, taking into account:
   - survey results
   - information obtained from interviews,
   - as well as comments and opinions of the teachers of the course,
   - and the time taken for the development of this educational project, both by teachers and students.

In the main practical task, students organized themselves in groups of 5 persons in order to develop a Web application to register, consult and update the information related to the experimental subjects to be registered in the research project. They had two months to accomplish the development of their Web application. In this time, students even did some test to their systems. Anyway, these tests were done with artificial/imaginary data invented by the groups, as they did not access the biomedical data nor other personal data collected from the experimental subjects.

At the end of this development-test period, some one-hour seminars were held. Groups of students could optionally attend them: they were not mandatory at all. In more detail, three seminars were held:

Spanish Legislation about personal data: LOPD and RLOPD,cloud computing and their implications, and methodology to analyze and manage risks: MAGERIT methodology.

After that, the groups of students were asked to write a report where the risks of the Web application that they have previously developed were analyzed. Moreover, some extra time (two weeks) was provided to the students to allow them to improve the implementation of their Web application.

Technologies

In relation to the technologies used to develop those activities, several Web technologies were explained during the course and were also proposed to develop the Web applications:

- Hypertext Markup Language (HTML). Two one-hour lessons were performed about this topic. In particular, on the first session, the structure of the language, basic features and how to edit html files was explained by using multiple examples. On the second session, students created their own html files and performed the exercises in the html tutorial by World Wide Web Consortium School (W3C School).

- Cascading Style Sheets (CSS). Two one-hour lessons were also performed about this topic. In particular, on the first session, the syntax of the language and how to include css styles in html code was explained by using multiple examples. On the second session, students created their own css files and performed the exercises in the css tutorial by World Wide Web Consortium School (W3C School).
- Apache-Tomcat. Due to the fact that the students registered in the course have learnt to program in Java in previous courses, we decided to use Java Enterprise Edition (JEE) as computing platform. In particular, one-hour lesson was performed to explain the structure of a JEE Web application and how to deploy and undeploy it in Apache Tomcat.
- Relational databases (Oracle, PostgreSQL, and MySQL). This topic is a key issue in the development of Information Systems. However it is out of the scope of the Information Systems course where this experience was developed, as all students registered in it have already coursed an introductory course focused on databases. So, only a one-hour class was dedicated to review some aspects such as: installation of MySQL, the Entity-Relational model (E-R model), the relational model and Standard Query Language (SQL). Moreover, a one-hour class was dedicated to review some concepts related to the Java Databases Connector (JDBC) API.
- Extensible Markup Language (XML). Two one-hour lessons were performed about this topic. In particular, on the first session, the structure of the language, basic features and its main uses were explained by using multiple examples. The second lesson was a hands-on session where students performed the exercises in the XML tutorial by W3C School.
- Java Server Pages (JSP). Three one-hour lessons were dedicated to explain diverse examples to dynamically create Web pages based on HTML and XML.

Nevertheless, students were allowed to select other technologies and frameworks to develop their information systems. Thus, some of them selected NoSQL database technologies such as MongoDB and scripting languages such as Node.js, among others.

The different groups of students participating in this experience could install the environment to develop their projects in personal computers (PC) connected to the Internet available in a teaching laboratory in the *Escuela de Ingeniería y Arquitectura*. Nevertheless, teachers suggested them to use virtual machines in order to promote the flexibility and an easy scalability of their solutions. Besides, from an economic point of view, the use of virtual machines requires a lower initial inversion. In more detail, the use of virtual machines has the following advantages with respect to the acquisition and maintenance of a hardware infrastructure:

- flexibility to increase/decrease the capacity of computing, the size of memory and the storage space of the different servers in a few minutes if it is required,
- payment for the use of the infrastructure and not for the acquisition and maintenance of it and
- higher levels of integration, security and network services, as they have been already proven in many different contexts.

These advantages also imply a lack of direct control over infrastructure, which requires the study of the clauses related to the security of the cloud services. Thus, the conditions of several cloud services were studied. In particular, the cloud services offered by Amazon, Microsoft, Google and other national companies were analyzed.

After a first review, teachers decided to support the use of the platform offered by Amazon instead of other options available in the market. In spite of being a little more expensive than other alternatives such as Google Compute Engine or Windows Azure, it was considered for the following reasons:

- it is the leader of the cloud solutions market and
- it provides a wide range of tools to monitor and analyze the behaviour of the virtual machines and the resources consumed by them.

Generic services provided by Amazon do not guarantee that the requirements established by the LOPD are fulfilled. However, it is possible to sign contracts with clauses where such requirements may be imposed. In more detail, the generic services offered by Amazon may store and process data in foreign territory (outside Spain), such as in the United States (USA), China or Japan.

In the Article 33 of the LOPD and in the directive EU 95/46/CE, it is indicated that temporal or permanent transfers of personal data to countries that do not belong to the European Union are not allowed if those countries do not provide a level of protection similar to the one provided by LOPD. Moreover, in case of that level of protection exists, then an authorization of the Director of the AEPD is needed before doing the transfer.

Results and Discussion

Generally, during the development of current practices and problems, students often work with simple examples that do not motivate them. In addition, topics related to legislation and ICT in a Degree on Computer Engineering or Computer Science do not usually appeal to students. So, through this experience students increased their knowledge of the subject, Information Systems, and especially increased their expertise and know how, as they had practiced through a real professional approach. In addition, students had learnt it in a more entertaining way, thanks to their motivation, because the obtained result, the information system they developed, would be used on a project that was already ongoing. Thus, teachers observed that during the course students were more aware of the need to accomplish with legal issues than in previous courses. Moreover, students considered that taking into account legal issues improved the security and maintenance of their systems.

On the one hand, the fact that after the two extra weeks given to students in order to refine their systems, the common improvements of the systems designed and developed by the students who attended the seminars were different to those carried out by students who preferred not to attend them is representative. The most common improvements introduced by the students who attended the seminars (described in previous section) were encrypting the passwords of the users of the Web application stored in the databases, establishing politics to force the users of the Web application to update their passwords after a period of time and performing backups of the databases of the system.

Contrarily, groups of students who did not attend to the seminars improved the Web interfaces of the systems and solved some bugs related to the connections to the databases to allow concurrency.

On the other hand, students who attended to the seminars got better marks in the questions related to legislation issues in the final exams (a test and some short questions).

After the final evaluation results were published, teachers of the subject also interviewed four students (two from the course were the experience was carried out, 2014-2015, and two from the previous one, in order to compare the assimilation of concepts). The students of the previous year did not remember basic concepts such as the different security levels or the different user roles defined in the LOPD. Besides, they said that legal issues were not important for them and that they did not like them. In contrast, students of the current course claimed that they would like to know more about methodologies and legal issues.

Conclusions

The feedback provided by the students and teachers involved in this project indicate that legal concepts are better understood when students are involved in a real project. Besides, the results indicate that the students involved in this project obtained higher marks than students that did not participate. Moreover, students were motivated to consider legal issues on their applications, as they appreciated that this leads to improve the security and maintenance of their systems. We think that they became motivated due to the relation of the activities they do with something real, as they realised the need of safety.

In our opinion, the main result of the work here presented is that change of mind: thanks to it, students finally were motivated to accomplish with legal issues.

Sustainability and Transferability

Regarding to sustainability, this experience would be repeated in subsequent years in the same subject, using as a basis new projects that would be useful for the implementation of the tasks that are part of the course. So, it would facilitate the learning of those tasks.

Regarding to transferability, the idea of approaching reality through professional learning in a professional development project to an academic degree course could be exported to other related subjects. In fact, it is planned to export this experience to other subjects that the authors would teach in the future.

Future Work

In relation to the subject Information Systems, current academic year (2015-2016), the new students will be involved in a new innovation project, in particular they will design an information system for an enterprise focused on the logistic sector, a very important one here in Zaragoza, city where the experience is going to be held.

In more detail, students will be asked for designing a device in order to register and transmit the temperature of a set of trucks that will be travelling around Europe by means of *Arduino* components (Lozano & Trillo-Lado, 2015). Moreover, the different teams of students must also design and implement an information system to analyze and monitoring the data of the different devices.

In order to develop this experience with the students of the Information Systems course of the academic year 2015-2016, it is planned to apply for a *proyecto de innovación* (teaching innovation project) to the Universidad de Zaragoza, with the main objective of approaching Information Systems students to professional practices in order to be concerned about legal and normative issues from the beginning of the first stage of any software project.

Besides other interesting matters already taken into account in this paper, we are also interested in what concepts; students that already carried out the experience explained in this paper, will remember an academic year after having taken the Information System course presented on this paper.

Acknowledgements

This work has been supported by the Red EULES, from the Universidad de Zaragoza, the project PIIDUZ_14_529 from the Universidad de Zaragoza, the project CUD2013-11 from the Centro Universitario de la Defensa de Zaragoza, the project TEC2014-54143-P from the Ministerio de Economía y Competitividad and the action COST Keystone IC1302.

References

Aiger, Montserrat, García-Laencina, P., Lozano, M., Peláez Coca, M.D., Roca-Dorda, J., Roca-González, J., Rodríquez-Bermudez, G., Sancho, J.J., Serna, J. & Trillo-Lado, R. (2014). Indicadores somáticos en el estudio del rendimiento en el personal de Seguridad y Defensa. In Dena Arto, A., Sánchez Rúa, M.T., & Martínez Torres, J. (eds.) *Actas: II Congreso Nacional de i+d en Defensa y Seguridad, DESEi+d 2014* (pp. 527-535). Ed. Centro Universitario de la Defensa Zaragoza.

Dranca, L., Lozano, M., Martínez Cantín, R., Pastor, J.J., Peláez Coca, M.D., Sancho, J.J., Torralba, M., Bailón, R., Trillo-Lado, R.; Arcarazo, L.A., Barrios, G. & Buatas, M. (2013). Identificación de situaciones de estrés, privación de sueño y sobreentrenamiento mediante alteraciones en la variabilidad del ritmo cardiaco. In González-Marcos, A.P. (coord.) *Actas: Congreso Nacional de I+D en Defensa y Seguridad-DESEi+d* (pp. 535-542). Madrid: E.T.S.I. Telecomunicación, UPM.

Escolano, C., Navarro-Gil, M., Garcia-Campayo, J. & Mínguez, J. (2013). EEG-based Upper-Alpha Neurofeedback for Cognitive enhancement in major depressive disorder: a preliminary, uncontrolled study. International Conference of the IEEE Engineering in Medicine and Biology Society, Osaka (Japan).

European Union (2012). Proposal for a regulation of the European parliament and of the council on the protection of individuals with regard to the processing of personal data and on the free movement of such data (General Data Protection Regulation). Brussels, 25/1/2012.

Fernándes Sánchez, C.M., & Piattini Velthius, L. (2012). Modelo para el gobierno de las TIC basado en normas ISO. AENOR Ediciones.

Izquierdo, D., Gil, E., Aiger, M., Lozano, M., López-Jurado, M.I., Lázaro, J., Gracia, A., Garcés, I., Bailón, R., Peláez-Coca, M.D. & Bea, J.A. (2015). Monitorización on-line de señales biomédicas para prevención de accidentes hiperbáricos en actividades subacuáticas. In *Actas: III Congreso Nacional de i+d en Defensa y Seguridad DESEi+d 2015*. Vigo: Centro Universitario de la Defensa Vigo.

Javor, A., Koller, M., Lee, N., Chamberlain, L. & Ransmayr, G. (2013). Neuromarketing and consumer neuroscience: contributions to neurology. In *BMC Neurology*, 13:13 doi:10.1186/1471-2377-13-13.

Lozano, M. & Trillo-Lado, R. (2014). Experiencia en el desarrollo de un sistema de información para la gestión de señales biomédicas en PYMES y grupos de investigación emergentes. In Dena Arto, A., Sánchez Rúa, M.T., & Martínez Torres, J. (Eds.) *Actas: II Congreso Nacional de i+d en Defensa y Seguridad DESEi+d 2014* (pp. 637-644). Ed. Centro Universitario de la Defensa Zaragoza.

Lozano, M. & Trillo-Lado, R. (2015). Monitorización de la temperatura en camiones frigoríficos. In *Actas: III Congreso Nacional de i+d en Defensa y Seguridad DESEi+d 2015*. Vigo: Centro Universitario de la Defensa Vigo.

Lozano, M. (Coord.; 2014). *Acercamiento a la realidad profesional: desde un proyecto informático a la asignatura Sistemas de Información*, PIIDUZ_14_529. 2014-2015.

Peláez Coca, M.D. (I.P.; 2014). Identificación de situaciones de disminución del rendimiento del militar, basado en la relación de la variabilidad del ritmo cardiaco con el estrés y la privación de sueño, CUD2013-11. 1/1/2014-31/12/2016.

Pérez San-José, P., Gutiérrez Borge, C., Álvarez Alonso, E., García Pérez, L. & de la Fuente Rodríguez, S. (2012). Estudio sobre seguridad de la información y continuidad de negocio en las PYMES españolas. Informe Instituto Nacional de Tecnologías de la Información.

Annex I

Practice 1: Installing Web Applications and Designing Web Interfaces

Information Systems in the Computer Science and Engineering Degree

Escuela de Ingeniería y Arquitectura (EINA), Universidad de Zaragoza

25th September 2014

1. Goals

Web applications run in at least one Web Server. In this environment, users access to the application by mean of a general purpose client (e.g. a Web browser on a PC, mobile phone, etc.). Since 90s decade, Web applications are characterized by a static content (html, pdf, images, etc.) and dynamic content generated by the Web server when users submit different requests. In this practice, we will focus on basic concepts related to Java Enterprise Edition applications (JEE applications). In addition, students must design and implement the interface of a Web application that they will develop along the course. In more detail, the goals of the work here proposed are:

- Installing the Web Application Server Apache Tomcat.
- Seting up a simple Web application.
- Designing the View layer of a Web application whose purpose is: the registration, updating and storage of personal data and biomedical signals of a wide set of persons (experimental subjects).

It is recommended to use the development environment JDK 1.7.

2. Content

This work has two main blocks. The first one focuses on installation of the Web Server Apache Tomcat, while the second one requires the design and the implementation of the View Layer of the Web application that we will develop along the course by using HTML and CSS. Optionally, JavaScript and libraries such as bootstrap can be also used. Besides, it is required to pack and install the component view (the View Layer) in a Web Server.

2.1. Installing a Web Server: Apache Tomcat

Firstly, downloading the file *apache-tomcat-7.0.29.tar.gz* available in the Web repository of the course and unzipping it is required. Scripts *start-up.sh* and *shut-down.sh* located in folder */bin/* can be used to start-up and to stop the Web Server, respectively. By default, the Web Server is available in the port 8080 but this configuration can be changed on file */conf/server.xml*.

2.2. Designing with HTML and CSS: View Layer

Each group of students must design and develop a different Web Information System that allows the researchers involved in the project *Identificación de situaciones de disminución del rendimiento del militar, basado en la relación de la variabilidad del ritmo cardiaco con el estrés y la privación de sueño* register, updating and deleting personal data and biomedical signals of experimental subjects that participate in the different experiments performed by the research team.

Users of the Web information system will be the researchers and technicians of the research project. Thus, different users must be able to register in the web application to be developed. After their registration, the person in charge of the research project (the IP or Investigadora Principal in Spanish, Main Researche in English), will give them the permissions to insert, update and/or delete data of the different experimental subjects participating in the experiments according to their role in the project. By default, a user registered into the system does not have any permission to manipulate this data. Every user (technician and/or researcher) must introduce the following data to complete his/her registration in the system: data when she/he ask for the registration, name, surname, Fiscal Identification Number (NIF; Número de Identificación Fiscal), address, e-mail, telephone number and password to access to the system. The system must allow to storage at least the following data of each experimental subject participating in an experiment: date of birth, sex, how many cigarettes he/she smokes per day, how much alcohol she/he drink per week and the results of the different tests.

The activities done by the researchers or technicians in the system (insertions, deletions, reports, and updates) must be logged. The following data must be stored for each activity: date and time when it was performed, and a comment indicating the activity done.

Take into account that the design and the implementation of a database is needed to store all the information generated by the Information System.

Requirements

The interface (View Layer) must allow the following operations:

- Allowing a researcher to log in in the system.
- Giving Permissions to new users registered in the system. This operation can only be performed by the IP.
- Recording data of a subject or patient in an experiment or test.
- Updating or deleting data of a subject in a test (only if the researcher who entered the data is the same as the one updating or deleting the data).
- Given a particular researcher, listing all the activities he/she has performed in a time interval.
- Given a particular researcher, reporting all patients with whom he/she has worked.
- Given a particular patient, reporting which researchers have had contact with him or her.
- Given a particular patient and test, reporting the data related to that test and subject.
- Given a particular researcher, displaying her/his personal data (address, telephone, etc.)

Appropriate forms and templates of Web pages must be designed. It should be taken into account that some operations can fail and that it is also needed to design Web pages for system failures. Finally, notice that, in next sessions, this work will be improved and the dynamic behavior of the system will be programmed.

Installing a Web application in a Web Server

If it is a JEE Web application, firstly, a War file should be created. War files are created in a similar way to the Tar files by using the following instruction: *jar -cvf webApplication.war folderToBePacked*, and must have the following structure:

- *olderToBePacked/WEB-INF/classes*: In this folder all .class files are stored and organized in different folders according to their packages. In this work this folder has no content.
- *olderToBePacked/WEB-INF/lib*: In this folder all libraries (jar files) that the web applications requires are stored. In this practice this folder has no content.
- *olderToBePacked/WEB-INF/web.xml*: a setup file for the Web application.
- *olderToBePacked/*: files and templates related to the view layer of the web application (e.g.: HTML files, images, CSS, JSP files, etc.) organized in folders according to some criteria chosen by developers.

WEB-INF can be only accessed by the Web server. However, the clients/users of the Web application can access to the view layer.

The *web.xml* file has a specific structure and allows developers to set up a great amount of paramenters (most of them are optional). Next, an example of a web.xml file is provided:

```
<?xml version="1.0" encoding="UTF-8"?>
        <web-app version="2.5" xmlns=http://java.sun.com/xml/ns/javaee
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="http://java.sun.com/xml/ns/javaee
        http://java.sun.com/xml/ns/javaee/web-app_2_5.xsd">

        <description> Hello World </description> <display-
        name>Test</display-name>

</web-app>
```

After creating the War file, this must be copied in the *webapps* folder of the Web server. When the Web server starts-up, this file will be unzipped and the web application will be deployed, i.e., users could access to the Web application by means of their browsers (they have to type the following address if the web application has been installed locally: *http://localhost:8080/nombreAplicacion*).

3. How to submit the work for evaluation

The following files should be sent to own supervisors:

1. A text file called *authors.txt* with the NIP (Personal Identification Number, used at University), surname and name of the authors of the work. This information will be written in the first lines of the file. After that, the students must sum up which steps have done to develop the work (resources, Tools, how they have distribute the work, etc.), i.e., they must explain the scheduling and the methodology that they have followed. Which difficulties and problems had to be solved can be also included in this file.
2. A war file (or an equivalent file) to be installed on a Web Server.

Work should be submitted by means of Moodle 2 by 30th October 2014.

4. Recommendations and evaluation criteria

After working groups finish their practice tasks, they should be presented to the teachers in charge of the course. So, an appointment should be agreed with one of the teachers. During the public presentation, supervisors ask questions to the students about the work presented. Besides, the system sent must accomplish all the requirements previously indicated, run properly in any computer. Remember that copies are not allowed. It is also important to submit smart code (where debugging code and messages have been removed). The following aspects will be also considered:

1. structure and design of the Web site (menus, different options, styles, etc.),
2. usability and accessibility of the Web site and
3. comments and indentation of source files.

Annex II

Practice 2: Design, Implementation and Deployment of a Web Information System

Information Systems in the Computer Science and Engineering Degree

Escuela de Ingeniería y Arquitectura (EINA), Universidad de Zaragoza

21st October 2014

1. Goals

Web Information systems are composed of Web applications, hardware, protocols and users with different roles. In this work we focus on the design, implementation and installation of Web applications. Web applications runs in at least one Web Server. Users access to the application by mean of general purpose clients such as web browsers on a PC, mobile phone, etc. Web applications are characterized by their static content (html, pdf, images, etc.) and their dynamic content generated by the Web server when users submit different http (or https) requests.

Generally, Web applications consult different databases (most of them relational data bases) to generate the dynamic content. So, in this work it is recommended to use a relational DataBase Management System (DBMS) compatible with Java Data Base Connection (JDBC) such as MySQL to implement the persistence layer of the application.

The goals of this work are:

- Setting up the work environment (Web server, DBMS, drivers to connect the database to the web server.
- Designing and implementing of the database required to store the data manipulated by the web application required.
- Designing and implementing the components in charge of interacting with the database.
- Designing and implementing model layer of the system.
- Enriching the previous view layer developed in the previous work (Práctica 1).
- Creating a technical report where the decisions and methodology used to develop the work to be explained.

It is recommended to use the development environment JDK 1.7, MySQL and Apache Tomcat.

2. Content

This work has three main blocks. The first one is focused on the installation of the work environment. Students must decide which technologies will be used in the development of their Web applications and setup their work environments. The second part is focused on the design and implementation of the Data Access Layer and the Model Layer of the web application required. Finally, the third part is focused on integrating the View Layer developed in the previous work (Práctica 1) with the Data Access Layer and the Model Layer, i.e. on giving the dynamic behavior to the previous web application. Finally, students must write a report where all decisions taken during the development of the work are justified and described (methodology, costs, technologies used, etc.).

If a JEE approach is followed then, the War file will have the following structure:

- *olderToBePacked/WEB-INF/classes*. Folder that contains class files that implement the Data Access Layer and the Model Layer. Moreover, if some other component is required, then it will be also in this folder.
- *olderToBePacked/WEB-INF/lib*. Folder that contains the libraries (e.g. jar files) used by the different components of the Web application. The driver needed to interact with the database should be in this folder.
- *olderToBePacked/WEB-INF/web.xml*. The setup file of the web application.
- *olderToBePacked/*. Files that implement the View Layer of the web application (e.g.: HTML files, images, CSS, JSP files…) organized in folders according to some criteria defined by the developers.

After creating the War file, this must be copied in the *webapps folder of the Web server.*

3. How to submit the work to be evaluated

Students must send the following files to their supervisors:

1. A text file called *authors.txt* with the NIP, surname and name of the authors of the work.
2. A war file (or analogous file) to be deploy in a JEE Web server (or other similar web server).
3. A tar (or zip) file that contains a folder called src that contains source files implemented to develop the Web application.
4. A pdf file that the report where the steps to develop the web application are explained.

Students must submit their work by means of Moodle 2 by 7th January 2015.

4. Recommendations and evaluation criteria

After students submit their works, they must present them to the professors in charge of the subject. So, an appointment with the professors must be scheduled. During the presentation of a work, professors can ask questions to the students about the work. Besides the system sent must satisfy all the requirements indicated previously, work properly in any computer and must not have been copied. It is also important to submit clean code (where debugging code and messages have been removed). The following aspects will be also considered:

1. The structure and packages of the web application (methods, attributes of each class, the visibility of the methods and the attributes, etc.)
2. The usability and accessibility of the Web site.
3. The comments and indentation of the source files.
4. The structure and content of the report. Syntax and grammatical errors should be avoided.

PART V

Higher Education and Industry

Chapter 16

MOOCs as a teaching method and tool to connect higher education and professional experience? A Case study

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Abstract: This paper describes results from a student-made MOOC (Massive Open Online Course) on Collaborative Learning. We aim to explore the potentials of MOOCs for enhanced in-class learning and to connect stakeholder groups which were usually separated in learning. The main focus of interest lies on two aspects. Firstly, to explore the potential of using the process of creating a MOOC as a teaching method and secondly, to get insights into the affordances and outcomes linked to a cooperation with a knowledge-based company during the course of events of the MOOC. Both concepts aim for an improvement of quality in higher education by combining the concept of "learning by doing" with the initiation of communication between students and professionals in the field. The data shows that employing the task of building a MOOC as a teaching method is a very worthwhile didactic approach to initiate a complex and authentic learning scenario. In addition, the outcome indicates that the realized level of participation in the MOOC is expandable.

Keywords: Collaborative E-Learning, MOOC, Higher Education, Professional Experience

Introduction

The diffusion of MOOCs and the corresponding public and scientific discussion on the topic sparks the field of E-Learning in many ways and with great impact. In September 2015, the European MOOCs Scoreboard lists 1,771 European MOOCs. It is therefore not surprising that research on MOOCs is on the rise and encompasses a wide span of topics. Amongst others, Yousef, Chatti, Schroeder, Wosnitza and Jakobs (2014), the Department for Business Innovation & Skills (Haggard, Gore, Inkelaar, Lawton & Katsomitros, 2013) and the Norwegian MOOC Commission sub-report (*Time for MOOCs*, 2013) provide an overview and a review of the literature used in this field of study. According to that, the didactic configuration of learning processes in MOOCs can be seen as an important field of research. The most prominent debate on this subject is probably on the differences of cMOOCs vs. xMOOCs. MOOCs originated as learning environments that correspond to and realize connectivist ideas of (cooperative) learning (cMOOCs) (Downes, 2010). Connectivism stresses the importance of networks and connections of and to learning resources for learning and states that “learning and knowledge rests in diversity of opinions” (Siemens 2005). The postulates of connectivism can be easily related to socio-cultural and socio-genetic approaches of cooperative learning (Kop & Hill, 2008). Seen from this perspective, connectivist MOOCs (cMOOCs) have the potential to realize Knowledge Building Communities, as argued by Scardamalia and Bereiter (1994) and lifting them to a higher social level, thus enhancing learning quantitatively as well as qualitatively.

In contrast, the rising popularity and media presence of MOOCs are the result of the success and large audiences of courses offered on platforms like Edx, Udacity and Coursera that predominately follow a docent-centric knowledge distribution metaphor (xMOOCs) (Blom, Verma, Li, Skevi & Dillenbourg, 2013). One may argue that this ”massification of learning” (Yuan & Powell, 2013) comes with a price: a rather low level of instructional quality (Margaryan, Bianco & Littlejohn 2015), and learning scenarios which can often barely claim to address the higher levels of learning goals as described by different taxonomies, e. g. synthesis, evaluation, or metacognitive knowledge (Krathwohl, 2002). Hence, at present, learning experiences in MOOCs are often far-flung from the quality of discourse and interaction based learning processes as argued by theoretical approaches that aim beyond a knowledge acquisition metaphor, e.g. O'Donnel (2006), Scardamalia and Bereiter (1994), Slavin (1996), Siemens (2005). But the current debate on learning in MOOCs should not be restricted to a rather dichotomic discourse on “antiquated” and “up-to-date” views on learning. The concept and diffusion of MOOCs is directly connected to the idea and the adaption of socially unlimited communication. Seen from this point of view, MOOCs are an opportunity and playground to think of learning as an interaction of different people and groups in new ways.

This is the starting point of our work. We aim to explore the potentials of MOOCs for enhanced in-class learning and to connect stakeholder groups which were usually separated in learning. The first goal is to explore the concept of MOOCs as an in-class teaching method in which students are given the task to draft, implement, execute and evaluate a MOOC. Such a didactic setting can be seen as a complex and authentic task to initiate and foster self-initiated and autonomous learning on part of the students.

The second goal is to link theory and practice by connecting students with practitioners. Students should elaborate basic concepts and theories for practitioners of the profession. In turn, practitioners should provide feedback with regard to the needs and experiences of their daily work life, thus enriching the learning experiences of the students. In the following, the configuration and results of an exploratory case study are described. The paper starts with theoretical considerations about the learning-related added values of this MOOC scenario.

Then, the configuration of the MOOC and its execution are delineated. Following that, the outcomes are analyzed. The paper closes with an estimation of the added values and the limitations of this concept.

Approach and Concept

Figure 1 gives an overview of the structure of the MOOC and the stakeholders’ interaction in this case study to illustrate the following argumentation.

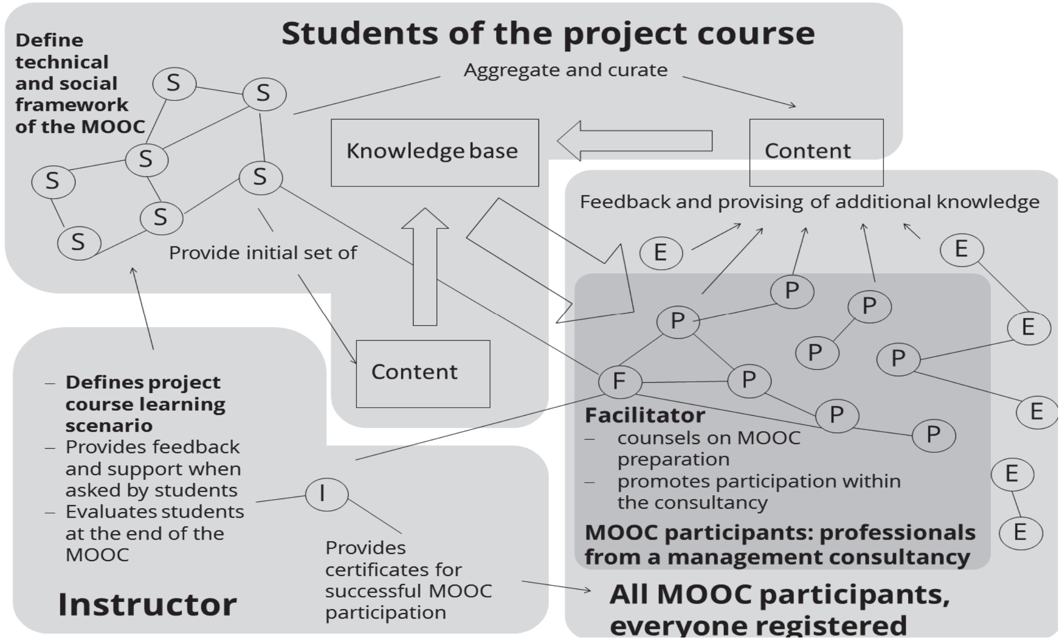

Figure 1. MOOC structure: interaction of stakeholders

Organizational context of this MOOC

Our didactic scenario is complex. It encompasses a regular project course as an internal learning scenario at the university and a MOOC which originated as a result of students learning activities within the project course. The course in which the MOOC is developed and executed is a project course and part of the module “E-Learning”. Participants are advanced students of the master´s programs “International Information Management” and “Information Management and Information Technology” at the University of Hildesheim. They collectively acquire practical skills and knowledge with regard to a specific project task within the wider topical area of the modules’ syllabus. In addition to content-related expertise, the students should also develop project management related competencies. In short, such a project course corresponds to a constructivist learning paradigm that emphasizes learning through active and social interaction in authentic scenarios, thus deepening the basic knowledge which has already been acquired in more knowledge transfer oriented courses. During the winter term of 2013 and 2014, the learning task of the project course was to build up and execute a MOOC on the topic "Collaborative E-Learning". The basic layout of this learning scenario was defined by the instructor of the project course, who is also the first author of this paper. To alleviate differentiation between the two courses within the didactic scenario, we refer to the project course of the students of the master´s programs as PC-EL and to the MOOC on the topic collaborative learning (which is developed in PC-EL) as MOOC-CL.

Actor group and roles

Table 1 gives an overview of stakeholders and their roles in this learning scenario as defined by the instructor at the start of the project course.

Table 1. Stakeholders and their roles in the learning scenario

Stakeholder	PC-EL	MOOC-CL
Students of the project course	Learners	Instructors and learners
University instructor	Instructor	Quality manager and recipient
Facilitator from a management consultancy	Advisor	Promoter and learner
Professionals from a management consultancy	-	Learners
Everyone interested	-	Learners

There are five stakeholder groups. Three of them are active both in the PC-EL and the MOOC-CL. The role of these actor groups is different in the two courses. In the project course, students are learners. They learn about E-Learning and knowledge management by developing an open learning scenario with regard to these topics, the MOOC-CL. Then, during the execution of the MOOC-CL, they act as instructors, providing the initial MOOC content. In addition, students initiate and moderate the learning process of the MOOC participants. The university instructor defines the learning scenario of the project course PC-EL. He is not actively involved in the execution of the MOOC-CL, but serves as a kind of quality manager with respect to the content provided by the students. Else, he is a passive recipient of the MOOC, not interfering with the course of events to maximize autonomous MOOC control on part of the project course students. The third actor is the facilitator from a management consultancy who is also the second author of this paper. Whereas the instructor defined and controlled the learning scenario of the PC-EL, the task of the facilitator was to announce and promote the MOOC-CL within the cooperating management consultancy. During the MOOC development, he additionally gave advice to students concerning learning related information needs of the professionals in the consultancy.

The last two actor groups correspond to that type of participants who could be addressed as MOOC learners. In our scenario, the core target group were professionals in the field, that means knowledge workers professionally counseling customers with regard to knowledge related activities to foster information management and knowledge management in middle to large sized companies. Still, the MOOC-CL follows the "open paradigm" and is not restricted to a certain audience. Hence, the MOOC-CL is open for everyone interested.

Conceptual considerations on learning related advantages of the learning scenario

Why could it be worthwhile to employ the task of building up and executing a MOOC as an in-class teaching method? Why to connect higher education and professional experience in a MOOC based learning scenario? In short, such a scenario realizes a “learning by doing” approach and tries to initiate exchange between theory and practice by an ongoing dialog between students and professionals in the field.

For the students of PC-EL three core advantages can be stated: A) the learning scenario of PC-EL realizes an authentic and complex learning task. B) The MOOC-CL creates a space for discourse and feedback from the community. C) The MOOC-CL provides a room to build up online identity and reputation.

With respect to the management consultancy and its professional workforce and all learners in the MOOC-CL further advantages can be argued. D) The MOOC provides a free course to a topic which is relevant for professionals in the field. And finally, E) the MOOC offers businesses (especially the directly involved consultancy company) new options to get in direct contact with potential candidates for open positions.

In the following, the mentioned advantages A-E are elaborated.

A) Authentic and Complex Learning Task

Building up and executing a MOOC can be seen as a real life learning scenario that provides first hand E-Learning experience. As a complex task with no predefined solution, the MOOC assignment can be described as a natural group task (Cohen, 1994) in which students can only succeed when they coordinate and collaborate with each other. As Johnson, Johnson and Holubec (1998) state: “Positive interdependence is linking students together so one cannot succeed unless all group members succeed. Group members have to know that they sink or swim together.” As a first result, it is to state that the task of building up MOOC-CL realizes the central affordances of socio-constructivist learning. In addition, the students of the project course are the initial and primary content providers. That means students act as teachers. This can be connected to perspectives of cognitive elaboration (O’Donnell, 2006). By creating and collecting MOOC content related learning resources, course participants act as topical experts acquiring deepened topic-related knowledge by themselves. A problem could arise if the topic and contents of the MOOC are too complex or difficult. Then, the course participants could be overstrained and unable to handle the MOOC scenario. Thus, employing MOOC building as a learning method is probably not suitable when the learning content is very demanding.

B) Discourse and feedback from the community

PC-EL corresponds to a cooperative learning scenario. Therefore, one could expect the positive effects of small group learning, as argued by socio-cultural, socio-genetic, and motivational perspectives of cooperative learning. Additionally, the MOOC-CL opens up further opportunities for discourse and feedback from the MOOC community itself. The corrective perspective and input from the course instructor is extended and enhanced with the recognition and acknowledgment from the community, once it is active. Thus, the open teaching scenario could and should result in a win-win-situation for both the MOOC-community and the project course students, this is particularly true as the MOOC-CL participants from the management consultancy are practitioners with working experience in the field.

C) Online Identity and Reputation

The above-mentioned arguments focus on advantages seen from a cognitive perspective. One could also argue that there are positive motivational effects. Next to positive motivational factors like chaining individual and group success or perspectives of group cohesion (Slavin, 1996), one may also postulate positive motivational effects occurring in community settings or Web 2.0 contexts. The openness of MOOCs means that there is no theoretical audience and participation limit. With the MOOC-CL, students of the PC-EL expose themselves and their work to the whole web community. Thus, MOOC-CL is a part of the project course participants’ online identity. Therefore, MOOC-CL can be seen as an opportunity to work up one’s own online reputation. Furthermore, according to DiMauro (2012) “People participate online to help each other and be a part of a community”. In sum, being involved in a MOOC development and execution creates opportunities for motivational factors usually not present in other learning settings.

The aspects mentioned in A-C indicate that the task of building up a MOOC could be indeed a very worthwhile teaching method.

D) Free course for professionals and the web community

With regard to MOOC learners (cf. table 1) the MOOC-CL provides an open access knowledge base which can be permanently used. In addition to the interaction with the students of PC-EL, the learners within the MOOC could and should also become involved in knowledge communication with each other. Concerning such knowledge generation, the MOOC can be assessed as an environment which exhibits many of the socio-technical characteristics necessary for the development of communities of practice as argued by Wenger (1998).

E) Getting in contact with members of the future workforce.

This argument can be seen as a continuance of the argumentation to aspect C as stated above. As students present and expose themselves and their work to the web community, businesses are able to detect and recognize talents and directly get in contact with them. Seen from such a perspective, with the increasing shortage of skilled professionals in Germany and the increasingly important role of Social Media in the recruiting process (Institute for Competitive Recruiting [ICR], n.d.), the MOOC may even be assessed as a highly targeted resource for employee recruiting.

In sum, the mentioned arguments strongly indicate that both core aspects of this learning scenario, setting up the task of building up a MOOC as a teaching method and the interconnection of the resulting MOOC scenario with professional practice feature many desirable learning related characteristics. The scenario connects different stakeholder groups in new ways. Surely, the theoretical considerations argued here are just a first plunge into discourse and not the end of the discussion. The crucial point in our argumentation is to broaden the viewpoints which consider MOOCs primarily as an efficient way to provide learning for "big masses". Instead the concept should be used to explore new learning scenarios by connecting different stakeholder groups in novel ways.

MOOC configuration and execution

In the following, we describe the concrete configuration and the outcome of the case study. Results should give a kind of first proof of concept and deliver hints for improvement

Figure 2 provides an overview of the course of events of the PC-EL and the MOOC-CL.

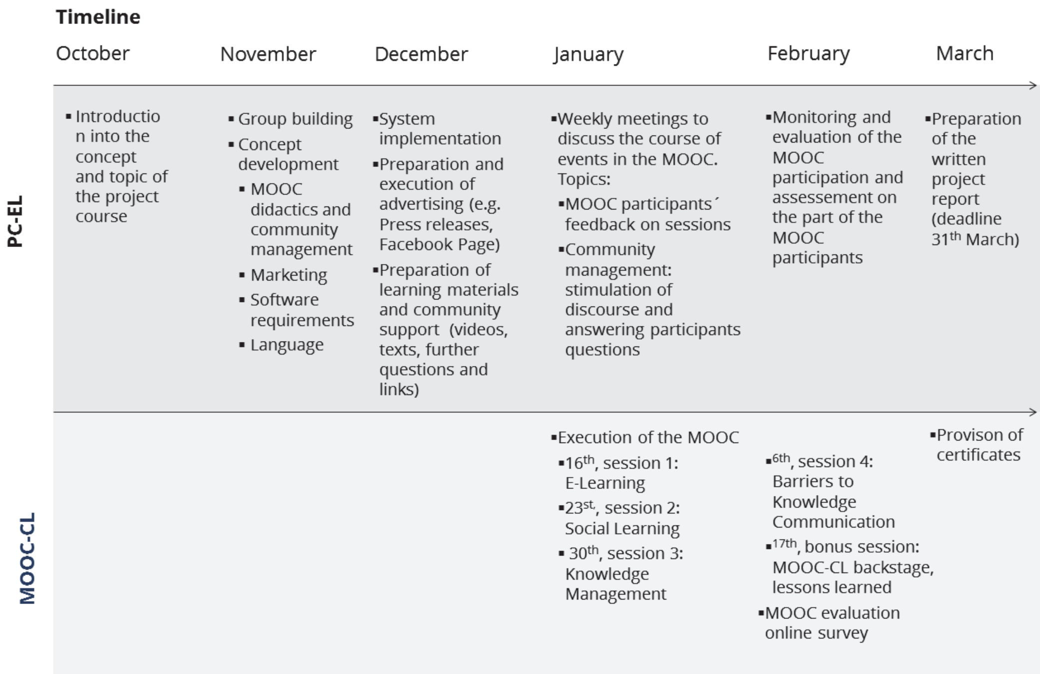

Figure 2. Course of events of PC-EL and MOOC-CL

At the start of the project course, the instructor introduced the students to the concept of the course and provided some basic suggestions concerning self-organization, group coordination, and work packages.

After that, the students took over the management of the course. The instructor restricted himself to a guide role, giving feedback only when explicitly asked for and providing infrastructural services, like preparing and handing out certificates to MOOC participants. From that date on, the students realized a truly self-controlled constructivist learning scenario. First, students determined basic aspects of self-organization and the MOOC-CL. As a starting point, it was decided to follow a connectivist paradigm in MOOC development. Hence, MOOC-CL should rather correspond to a cMOOC than a xMOOC. Group formation resulted in different groups: project management, content development, community management, controlling, software configuration and support, and marketing.

Next, the language of the MOOC was decided. Choices were English or German language. Language choice was very important as the number of potential MOOC participants from the management consultancy was largely dependent on the language in which the MOOC was deployed. In case of a decision for an English language based MOOC, the potential number of participants would have been much larger, encompassing the global workforce of the company, than in the case of a decision for the German language. In the last case, the number of potential participants would have been much lower, corresponding to approximately 200 participants, which reflects the number of knowledge management consultants with a German mother tongue. Nevertheless, students decided for the German language. This way, the number of potential participants from the management consultancy was rather limited. From the perspective of the instructor, it was the right decision because the students avoided another level of complexity. Although, all students speak English fluently, using a language other than German would have caused additional cognitive effort during MOOC preparation and execution. For the students, the MOOC scenario was demanding even if executed in their German mother tongue.

Following that, the content of the MOOC-CL, the time schedule and the number of MOOC sessions were decided. Every session was prepared and executed by a specific session or content group.

After the above mentioned basic aspects were determined, the MOOC-CL was prepared. CourseSites, a free MOOC software by Blackboard, was chosen as the software infrastructure. The choice was not without problems. On the one hand, the system provides the necessary technical features and was easy to setup and to configure. On the other hand, there were login and content submission related problems with Internet Explorer 9, the standard browser used by the participants of the management consultancy.

The marketing team decided on a broad range of advertising measures, including online as well as classic marketing channels. For content development a storytelling concept was worked out, telling the story of a student who faces different learning and knowledge management related problems as a recurrent theme throughout all four MOOC sessions. Videos (with a length of a few minutes) and photo stories were prepared as the primary format for knowledge transfer. External experts were also included in the videos. For visualization, the software tools Videoscribe, PowToon, and ComicLife 3 were employed. All videos produced for the MOOC can be found at *Mooc.*

In addition, to initiate and support knowledge development within the MOOC community, a specific community management concept was developed. Firstly, discussions for each session were prepared and initiated. In the course of the four sessions, a successively larger variety of communication and knowledge generation tools was provided. For each of the tools an initial inventory of content was provided. Finally, students prepared questionnaires in order to obtain an evaluation for each session and to give the participants an opportunity to post requests for following sessions.

As planned, MOOC-CL started on January 16th. 2015. Overall, the execution of the MOOC went smoothly. During the execution of the MOOC, in the in-class session of the PC-EL students discussed the feedback of the MOOC participants and also lessons learned from executing the MOOC sessions. One important feedback of the participants after the first session was that the discussion in the forum was cognitively demanding and should be structured more clearly. A suggestion from the content team of this session was to optimize communication with participants by reducing the time till feedback was given to the questions of the MOOC participants. Another suggestion was to finish learning materials earlier to gain some room for quality assurance, e.g. proof reading. Such improvements were implemented in the following sessions. Besides these kinds of cognitive input and enhancements, the degree of participation and the sentiment of the feedback of the participants were also very important for the motivation of the students of PC-EL. On the one hand, user feedback was perceived as predominantly positive by the students of PC-EL. On the other hand, the amount of participation of the professionals from the management consultancy was assessed as rather low. After the fourth session, for all participants of MOOC-CL, including the students of PC-EL, a final MOOC assessment questionnaire was prepared and executed. Participants of this survey, with the exclusion of the students of PC-EL, were asked, if they wanted to get a certificate of course participation. 19 participants requested the certificate. Lastly, due to participants´ positive MOOC reception, students decided to prepare the final in-class presentation in PC-EL as an additional session of MOOC-CL. This final session was held at February 17th.It can be found Hinter den Kulissen von ``Collaborative E-Learning: GemeinsamWissen erarbeiten.

Results and Discussion

The analysis is structured with regard to the different stakeholder groups in the two courses. First, learning processes and outcome for students in PC-EL are evaluated. Following that, MOOC-CL related values for the learners in the MOOC are discussed. Finally, both perspectives are brought together.

Learning success of students in PC-EL

The analysis of students´ learning success is based on the assessment of the participants' learning processes and outcome on part of the instructor and on the students' self-estimation captured by a survey at the end of PC-EL. According to the estimation of the instructor, the course of events as described in section 3 strongly indicates that the learning scenario successfully evoked a widely self-directed and self-controlled learning process on part of the students. In PC-EL, students were very active and highly involved. After the introduction in the course, which was given by the instructor, the students organized in-class and virtual learning activities autonomously. During the active phase of the MOOC-CL sessions, the students often decided to have additional face-to-face project course meetings. With regard to computer mediated communication, students produced than 1,400 postings on Google groups to organize their work.

As the preparation and execution of the MOOC-CL was well-founded and clearly presented in the final in-class presentation and elaborately described and argued in the project report, the group work was rated with the best grade, which can be seen as a direct measurement of learning success. This corresponds with the students' self-evaluation of their learning success. All 14 students took part in the final course evaluation. Table 2 shows the results.

Table 2. Results of the final course evaluation in PC-EL

Question	Mean Value (SD)
q.1) Workload	1.64 (0.48)
q.2) Learning success with regard to the content related aspects of the course	1.36 (0.72)
q.3) Learning success with regard to the project management	1.71 (0.59)
q.4) Charateristics of team work	1.21 (0.94)
q.5) Motivational effect of team work	0.86 (0.83)

N=14, measured on a 5-stage scale ranging from -2 (q.1, q.2, q.3 and q.5="very low", q.4="cooperative") to +2 (q.1, q.2, q.3 and q.5="very high", q.4="collaborative")

Learning success was assessed as high with a mean value higher than 1 (q.2 and q.3). Workload (q.1) was also assessed as high, indicating that students were highly involved. Motivation can also be interpreted as positive (q.5). The characteristics of group work can be estimated as very positive because the group process was judged as rather collaborative (q.4). Seen from socio-genetic and socio-cultural perspectives of learning, real collaboration has to be seen as a prerequisite for the occurrence of processes like cognitive conflicts, externalization of knowledge, and consensus building. Such processes in turn are causative for enhanced learning success in group learning. In sum, with a positive motivation, strong immersion and high learning success, students assessed their learning success very positively. Overall, both from the instructor´s perspective and students´ view on their learning, results with regard to learning success are very encouraging.

MOOC-CL values

Audience reach, participation and MOOC participant evaluation are analyzed to determine the value of the MOOC-CL.

Audience reach

Audience reach is captured with data provided by CourseSites which is further refined and aggregated. The data encompasses user actions between January 16th and February 28th.2015. Overall, till the end of February, 277 participants registered on MOOC-CL. Audience reach is operationalized as the number of unique users per MOOC session.

MOOC-CL started with 200 users in session 1. Thus, the MOOC can be assessed as rather small with regard to the number of participants. Nevertheless, a number of 200 users is not insignificant. It shows that the MOOC still reached an audience size corresponding to a multitude of standard courses. In the following sessions the number of users declined. This is a pattern typical for MOOCs (Koller, 2012). The different elements of the four sessions were used to a different degree. Over all four sessions data shows that videos are the media format used by the largest number of participants for knowledge acquisition and forums the primary channel for participation. On the due date of 12th of February (one week after the fourth session) the number of total requests in forums (n=17,657) more than doubles the amount of request of provided learning materials (n=8,115). This indicates that discourse and collaborative knowledge production formed a central part of the learning experience of all MOOC participants.

Knowledge generation and participation

Resources prepared by the students of PC-EL formed the core and bulk of the knowledge which was created in MOOC-CL. Students prepared 11 videos, 5 photo stories, 9 forums, 6 blogs and 9 wikis. Collaborative knowledge generation primarily focused on the discussions in the forums. 308 forum posts were written, roughly half of them by the students of PC-EL (147 posts) and half of them by the MOOC-CL participants (161 posts). Students of PC-EL moderated the forums strongly by initiating questions and answering participant posts. This explains the large fraction of posts of students of PC-EL. Such moderation led to substantial knowledge discourse. There were only two threads with no answers (single post threads and therefore "dead threads") and the mean thread length corresponds to 12,8 postings. Thus, knowledge generation in forums can be assessed as successful. In contrast to that, participative knowledge generation in other tools (blogs, wikis) was rather sparse.

A content related evaluation of tool configuration and collaborative knowledge generation delivers some tentative insights. During session 1 a meta discussion on the clarity and cognitive load of forum discussion took place, caused by the high number of postings per thread. In PC-EL this discussion was continued. Session 2 provided a large range of additional communication tools (blogs, wikis). Still, in this and the following sessions, user participation primarily took place in the forums. We cannot elaborate this aspect here, nevertheless we can easily see that usability of tools and media choice are important success factors of MOOCs. In addition, threads in which participants discussed own experiences and opinions on topics, got a higher rate of contributions than threads focusing on more theoretical aspects, e. g. reflections on the application and practicality of specific methods in professional experience.

Estimation of the participants of MOOC-CL

At the end of session 4, a final questionnaire was prepared for the MOOC-CL participants to obtain feedback with respect to the quality of the MOOC. 19 participants took part in the survey. 95% rated the quality of the MOOC as high or very high. With regard to learning, nearly 50% of the participants rated the videos as the primary means for knowledge acquisition. 85% of the participants assessed the forums as their preferred tool for interaction. Furthermore, users provided feedback with regard to their motivation for MOOC-CL participation and the learnings achieved. Data denotes two different motivations for MOOC participation. First, a MOOC format specific perspective. Participants took part because they were interested in MOOCs as a new "tool" for learning. The second motivation is content related. Participants also took part in MOOC-CL because they were interested in the topic of the MOOC "Collaborative Learning". According to the survey data, learnings achieved with respect to learning format related goals focused on aspects of MOOC organization and tools for video production. Feedback on content related learning goals indicates a consolidation of already available knowledge which was deepened in the forum discourse. The survey also collected open feedback with regard to possible improvements. With regard to this, survey participants often remarked on the clarity of the content structure and discussions. Again, this is a hint on the importance of usability aspects for learning and participation in MOOCs.

In sum, this chapter indicates manifold values of MOOC-CL for the professionals of the management consultant agency and the open web public. The number of participants shows a certain amount of interest and demand on the MOOC-CL. In addition, real discourse and collaborative knowledge generation can be observed. Finally, learning and learning outcomes are assessed as positive and of high knowledge value. On the one hand, these results sound encouraging. On the other hand, they need to be put in perspective. As a whole, audience reach is of a rather low level and therefore, the knowledge related values for the professionals of the management consultant agency and the open web public remains of limited magnitude.

Success of connecting higher education with professional experience

Finally, was the learning scenario able to invoke a connection between higher education and professional experience?

The answer to this question is already partly given with the summary of the MOOC-CL values in the last paragraph. Seen from an objective view inferred from CourseSites data with respect to audience reach and knowledge generation, the answer is: yes to certain extend. The estimation of MOOC participants is also positive. But what about the estimation of the students of PC-EL and of the professionals of the management consultancy? The views of both stakeholder groups are captured with different instruments. In the last in-class session of PC-EL there was a plenum discussion with regard to the success of the cooperation with the management consultancy. In addition, students explicitly analyzed and reflected on this aspect in the project report. Furthermore, the estimation of the management consultancy was compiled with a written survey (consisting of open questions) which was answered by the facilitator from the management consultancy.

Students of PC-EL assessed the exchange and communication with professional experience as basically successful, because there was a certain degree of mutual exchange and discourse. At the same time, they were somewhat frustrated and disillusioned by the low amount of participation.

In contrast, the response from the facilitator of the management consultancy was very positive. According to that, there were 20 employees of the management consultancy registered in MOOC-CL (10% percent of the target group aimed for). These MOOC-CL participants provided positive feedback with regard to the learning format and the content of the MOOC. There were two suggestions for improvement: usability of CourseSites and time resources for the MOOC. The fact that the used MOOC software only partly supported the standard browser of the company was assessed as a real participation hurdle. Moreover, usability of CourseSites was generally judged as rather low. In addition, MOOC participation competed with a high workload of the professionals. Thus, taking part in MOOC-CL corresponded to additional work.

In sum, we can conclude that the cooperation was basically successful. At the same time, we see that a successful cooperation strongly depends on the amount of participation of the management consultancy professionals. Regarding to this, the success rate was rather basic as only 10% of the target group took part in MOOC-CL. Two kinds of hurdles for participation were identified, organizational and technical factors. Both point to requirements which should be considered in further experiments. Firstly and probably most important, the effort taken in participating in a MOOC should be accounted for in the work schedule. Secondly, the compatibility between the MOOC software and the technical infrastructure of the company needs to be assured beforehand.

Conclusions

Finally, we provide an estimation of our case study. As written above, our approach is somewhat unique in the emerging area of MOOC research. Our didactic concept does not primarily follow the notion of a "massification" of higher education but aims to enhance the quality of existing learning scenarios by "enriching" them with a MOOC. The goal is to enhance learning by linking groups which are usually not connected in education. The case study encompasses two components and research interests which built upon each other. The first is the question, if the task of building up a MOOC is a worthwhile learning scenario. Results with regard to this aspect are very encouraging and confirm the positive results of a preceding case study (Griesbaum 2014).

On top of that, we aim to expand the MOOC related values for learning even further by explicitly linking theory and practice. The research interest focuses on potentials and hurdles of connecting higher education and professional experience. Here we get mixed results. To a certain degree, we are able to oberserve exchange and mutual learning. For that reason, this component of the case study can also be assessed as successful. On the other hand, results need to be put into context. As argued, there is manifold room for improvement. Especially a higher rate of participation and larger amount of collaborative knowledge generation are desirable. Therefore, we estimate these results as a minimum baseline. As an input for further research, the analysis reveals important organizational and technical hurdles with regard to the involvement and participation of the professionals. Organizational factors hint to the need of a much stronger integration of the MOOC and its work load into the professionals´ work schedules. In addition, seen from a technological perspective, not only usability but also compatibility with the technical infrastructure turned out as hindrances. One can easily argue how these problems can be solved or alleviated. But we need to weigh effort and gain against each other. Concerning the technical problems, standard software like CourseSites can only be enhanced by the company developing the system. In the short term, one either has the option to choose another system or to self-develop or customize software. The latter option is probably too costly in most cases.

Solving organizational hindrances on part of the corporation demands a high commitment to the MOOC on the company´s side beforehand. This is probably not that easily achievable as the return of invest may not be clear from the beginning on. At least, a significantly higher coordination effort between the university instructor and the corporation seems to be necessary. Again, the effort-output relation is unclear. Thus, with regard organizational hindrances, the necessary efforts on both sides to initially establish the cooperation may be prohibitive.

As an overall estimation, the conclusion here is that employing a MOOC as an in-class teaching method in the sense of a “students teaches the web community” approach can be seen as worthwhile. However, it is a teaching method, which deserves further exploration. The case study shows the limits of this concept but also indicates positive learning effects on part of the students and manifold values for the web community. At the same time, it turns out that a stronger and explicit connection to professional experience is not achievable that easily.

References

Blom, J., Verma, H., Li, N., Skevi, A. & Dillenbourg, P. (2013). MOOCs are More Social than You Believe. *eLearning Papers*, 33. Retrieved from https://oerknowledgecloud.org/sites/oerknowledgecloud.org/files/From-field_33_1.pdf

Cress, U. & Kloos, D. C. (2014). *Proceedings EMOOCs 2014, the Second MOOC European Stakeholders Summit, Feb. 10-12,* Lausanne (Switzerland).

Di Mauro, V. (2012). *Nearly 80% of People Participate In Online Community to Help Others.* Message posted to http://www.leadernetworks.com/

Downes, S. (2010). New technology supporting informal learning. *Journal of Emerging Technologies in Web Intelligence, 2,* 27-33.

Fournier, H., Kop, R. & Durand, G. (2014). Challenges to Research in MOOCs. *MERLOT Journal of Online Learning and Teaching, 10(1),* Retrieved from http://jolt.merlot.org/vol10no1/fournier_0314.pdf

Griesbaum, J. (2014). Students as teachers in MOOCs: The double gain of MOOCs as an in-class teaching method experiences from a student-made MOOC "Online data privacy”. *International Journal of Information and Education Technology, 4(1),* 29-34.

Haggard, S., Gore, T., Inkelaar, T., Lawton, W. & Katsomitros, A. (2013). *The Maturing of the MOOC. Literature review of Massive Open Online Courses and* *other forms of Online Distance Learning* (BIS Research Paper Number 130). London: Department for Business Innovation & Skills. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/240193/13-1173-maturing-of-the-mooc.pdf.

Ingham, A. G., Levinger, G., Graves, J. & Peckham, V. (1974). The Ringelmann effect: Studies of group size and group performance. *Journal of Experimental Social Psychology*, *10(4)*, 371-384.

Institute for Competitive Recruiting (2014). *Social Media Recruiting Report 2013. Endlich der Durchbruch?* Retrieved from http://www.competitiverecruiting.de/resources/Social+Media+Recruiting+Report+2013+.pdf

Johnson, D.W., Johnson, R.T. & Holubec, E.J. (1998). *Cooperation in the classroom*. Edina: Interaction Book.

Koller, D. (2012). MOOCs on the move: How coursera is disrupting the traditional classroom [Podcast]. In *Knowledge Wharton (2012)*, Retrieved Sep. 9, 2014 from http://knowledge.wharton.upenn.edu/article/moocs-on-the-move-how-coursera-is-disrupting-the-traditional-classroom/

Kop, R. & Hill, A. (2008). Connectivism: Learning theory of the future or vestige of the past? *The International Review of Research in Open and Distance Learning. 9(3)*. Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/523/1103

Krathwohl, D.R. (2002), A Revision of Bloom's Taxonomy: An Overview. *Theory into Practice, 41*, pp. 212-218.

N.A. (2013), *Time for MOOCs, Norwegian MOOC Commission sub-report*. Retrieved May 5, 2014 http://www.regjeringen.no/upload/KD/Time_for_MOOCs.pdf

Scardamalia, M. & Bereiter, C. (1994). Computer support for knowledge building communities. *Journal of the Learning Sciences, 3*, 265-283

Siemens, G. (2005). Connectivism: A Learning Theory for the Digital Age. *International Journal of Instructional Technology and Distance Learning*. Retrieved from http://www.itdl.org/journal/jan_05/article01.htm

Slavin, R.E. (1996). Research for the future. Research on Cooperative Learning and Achievement: What We Know, What We Need to Know. *Contemporay Educational Psychology, 21*, 43-69.

Wenger, E. (1998). Communities of Practice: Learning as a Social System. *Systems thinker, 9(5),* 1-10.

Yuan, L. & Powell, S. (2013). MOOCs and disruptive innovation: Implications for higher education. *eLearning Papers, 33*. Retrieved from http://www.openeducationeuropa.eu/en/download/file/fid/27007

Yousef, A.M.F., Chatti, M.A., Schroeder, U., Wosnitza, M. & Jakobs, H. (2014). MOOC. A Review of the State-of-the-Art. *Proceedings of CSEDU 2014 -6th International Conference on Computer Supported Education*, 9-20. Retrieved from http://www.openeducationeuropa.eu/de/download/file/fid/35609

Chapter 17
Convergence in Media Education Curricula

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Abstract: The paper sets out to investigate current university degree programs in selected European countries and in the United States with the intention of uncovering inasmuch they are suited to educate the workforce of the future. In an era of convergence, when the boundaries separating distinct industrial branches, professions, devices and skills are increasingly blurring or even vanishing (Jenkins, 2008), both workplace requirements and job profiles are changing dramatically and are transforming the ways people interact and communicate with one another. Academics as well as professionals have to bear these developments in mind. In form of an extensive content analysis, our study looks at the degree programs offered by universities in Europe and the United States on different educational levels (Bachelor, Master and PhD), scrutinizing to which extent these educational offerings have started to respond to current trends in the media (education) landscape. The paper is especially interested in whether universities are preparing their students to meet the requirements brought about by recent trends, such as altered business relations, new communication patterns, innovative working concepts and emerging leadership styles – all against the background of a globalized communication culture.

Keywords: convergence, education, cross-media, multimedia, university curricula, international comparison

Introduction

The past years have been characterized by considerable changes, which can be traced back to drastic alterations in the media communications landscape. New technologies are being developed on a regular basis, communication outlets are multiplying and media consumption is becoming more fragmented (Diehl *et al.*, 2013). The media landscape itself has undergone some far-reaching changes, all brought about by the rise of the Internet (Latzer, 2013). In this context, the most commonly used catchwords concern digitization and convergence. While the prior refers to “the conversion of text, pictures, or sound into a digital form that can be processed by a computer” (Oxford Dictionary, 2015), the latter is wider in focus, describing “the merging of distinct technologies, industries, or devices into a unified whole” (Merriam Webster, 2015).

Initially, convergence gained recognition as part of the overlapping between the telecommunications and broadcasting sectors (Pool, 1983), where it referred to “the blurring of boundaries between media, more precisely the blurring of traditional demarcation between telecommunications (point-to-point) and the mass media" (Latzer, 2013, p. 123). This rather narrow definition needs to be seen in opposition to a more open characterization proposed by Diehl *et al.* (2013), who regard "convergence as a phenomenon resulting from the merging and overlapping of different media functions and forms which once operated separately and independently" and also have a bearing on other, related sectors.

The past years have been characterized by an increase in communication vehicles, both digital and traditional (Perez Tornero *et al.*, 2008) which allow for user participation and exchange. Both technical and technological alterations have facilitated the use of the same gadgets and devices in the professional and the private spheres; in consequence, the boundaries separating personal and professional lives are blurring slowly but surely. Convergence, however, does not render old services redundant or calls for their elimination; rather, it suggests "complex, multi-layered interactions between 'traditional' (or 'old') communication cultures and emerging ('new') online, mobile media" (Allan, 2010, p. xiivf.). Given these immense changes, numerous areas of life are affected by convergence, such as media production settings, workplace environments, media consumption habits, business relations, industrial co-operations etc.

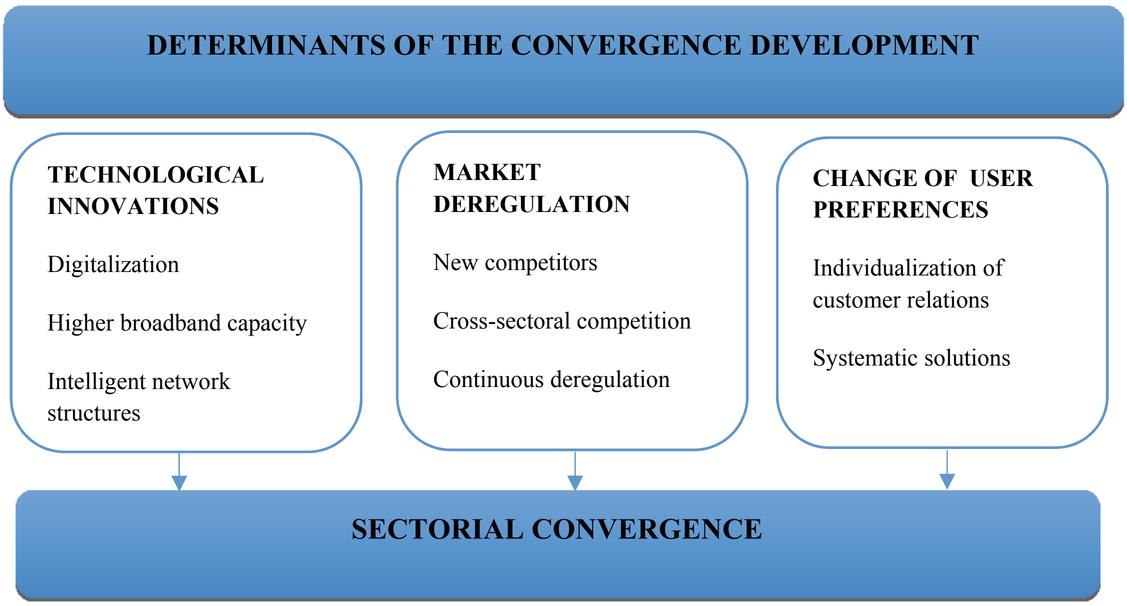

Figure 12: Determinants of Convergence (Wirtz, 2011; own illustration)

According to Wirtz (2011), convergence is – first and foremost – brought about by the following three phenomena that are deemed to change the professional world lastingly (see Figure 12). (1) Technological innovations, such as the digitalization of content into 0 and 1, are especially enabled by the rise of the Internet and higher broadband capacities. With it, also a faster and more seamless media distribution is enabled, in the course of which content can be appropriated, commented on and shared by 'empowered' consumers. (2) For businesses, the biggest challenge lies in determining how to deal with an advancing market deregulation. In the process, companies leave known territories to broaden their fields of operation, engage in new collaborations and co-operations, which force them to familiarize themselves with altered legal requirements and a rising number of competitors. (3) Finally, changes in user preferences spur companies into action: instead of offering mass products to the wider public, more demanding consumers call for individualized and tailored solutions; at times, they even enjoy to be part of the development process, simply because they have access to the latest technologies. Hence, they are no longer passive con*sumers*, but also active *pro*ducers – rendering them prosumers.

The communication landscape has been expanded as well. Convergence has eliminated the boundaries of previously independent industrial branches and, with it, led to a redefinition of established professional descriptions and job-related competencies. As a topic area, convergence is of as much interest to academia as it is to policy makers, marketers, and entrepreneurs. Their concerns, nevertheless, vary in interest: whereas industry representatives might be drawn to determine how convergence influences their innovative processes and strategic planning together with consumer responses, academia ought to be looking for reasons explaining how these new developments affect media consumption patterns as well as media production; from a legal perspective, also the need for changing regulations in the area of copyright presents a fruitful research endeavor (Latzer, 2013).

As professional matters increasingly become of personal concern, convergence needs to be tackled and addressed in an education setting as well. To guarantee for companies' lasting survival and success, universities from all over the world have to ensure that their educational program offerings are on the pulse of time – also against the background of an ever more connected and globalized world. For this reason, universities and other secondary educational institutions are required to address present-day challenges as well as new forms of communication and business strategies to adequately prepare students for their future professional careers, acquainting them with the tools and skills that might become of uttermost importance to corporate success, now and in the future (Arnolds-Granlund and Kotilainen, 2010).

Convergence

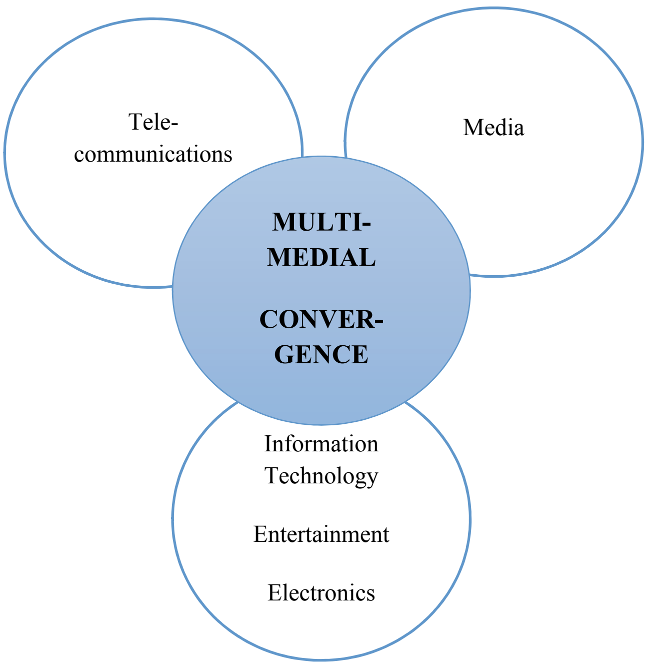

Figure 13: The Development of a Multi-Medial Convergence Sector (Wirtz, 2011; own illustration)

Convergence describes a phenomenon in the course of which formerly distinct areas of operation increasingly overlap and influence one another (see Figure 13). The common denominator serving all industries is the telecommunications or computer sector (Latzer, 1997), leading to the development of new services such as digital TV, wireless communication or the Internet/Web 2.0. Convergence originated out of the "three C's of convergent media, [namely] computing and information technology (IT), communications networks and digitized content" (Flew, 2008, p. 2). While it has often been exclusively ascribed to the media sector (Wirtz, 2011), limiting convergence to the media realm alone does not grasp the magnitude of a development that factors into a variety of related domains. This implies that media lies of the heart of convergence trends but the phenomenon itself affects areas such as "technological, industrial, cultural, and social changes" (Jenkins, 2008, p. 3).

It was also Henry Jenkins (2006: p. 154) who proposed convergence to be "occurring at various intersections of media technologies, industries, content and audiences". As a consequence, he distinguished five convergence processes: (1) *Technological convergence* is concerned with the transformation of content into digital data, may it be images, sounds and words and allows for a more rapid flow across multiple platforms. (2) *Economic convergence* describes the broadening of business operations, with more and more companies grasping the opportunity to produce digital and/or online content – albeit they do not possess expertise in this field. These tendencies are nourished by the desire to exploit synergies, whereby the performance of two companies in concert is assumed to be more fruitful than a single endeavour. (3) *Social or organic convergence* looks at how media usage patterns have changed due to people's multi-tasking habits, explained by terms like split attention or second respectively third screen. (4) *Cultural convergence* covers all new forms of productivity brought about by convergence-related role redefinitions. In an age of "spreadable media" (Jenkins *et al.*, 2013), users appropriate new tools to become active agents in the media production process, challenging companies and industry representatives, who have to court them across a variety of platforms ("multi-channel communication). (5) *Global convergence* alludes to the fact that not only industrial boundaries are disappearing, but also national borders have been weakened as the world becomes a "global village".

Jenkins has discussed the relevance of convergence for businesses only in relation to economic convergence; a more thorough and detailed account is offered by Wirtz (2011), who introduces another four economy-oriented forms of convergence: (1) *Product convergence*, the most prominent example, can relate to either the convergence of content, distribution channels, or devices through integrating different product functionalities into one unified design or service. It conditions (2) *business segment convergence,* which is expressive of those cooperation and collaboration trends. (3) *Supplier or company convergence* is concerned with a redefinition of the value chain as companies have started to acquire business units that help them fulfil the different steps in the product development process and reduce outside reliance (e.g., news content production, aggregation and distribution). This can be captured by terms like vertical or horizontal business concentration. Finally, (4) *sector convergence* presents a global trend, whereby mergers and acquisitions lead companies to become more powerful, integrating different services and products into their portfolios. Comparing these four types, intensity is least pronounced for product convergence but increases with every level, reaching its peak with sector convergence.

Published around the same time, Latzer (2009) even distinguishes between six forms of convergence: (1) *Technological convergence*, at times also labelled terminal or network convergence (Storsul and Fagerjord, 2008), refers to the unification of content by use of a universal digital code. (2) *Corporate convergence*, as part of an economic convergence development (Wirth, 2006), is conditioned by the first form, describing how companies now do not only operate in one single industrial sector anymore but also take on the role of suppliers for multiple branches. At times, even new, Internet-based corporations emerge (e.g., google, ebay; Latzer, 2009). (3) *Social-functional or socio-cultural convergence* is concerned with services leveraging their original fields of purpose, e.g., with telecommunications gaining ground in private entertainment and broadcasting being utilized for corporate purposes (Latzer, 2013). In this context, Henry Jenkins (2006) introduced the term "convergence culture". (4) *Receptive convergence* mirrors changes in media consumption patterns, while (5) *spatial convergence* alludes to dissolving national boundaries in an era of globalization. Finally, (6) *regulatory convergence or policy convergence* examines the challenges new media forms pose to regulatory bodies (Latzer, 2013).

Generally, convergence is perceived as a phenomenon that came into being from the merging and overlapping of different media forms and functions which were independent and operated on their own at one point in time (Diehl *et al.*, 2013). Having discussed a variety of established definitions, a combined approach will be pursued for the present chapter. We claim convergence to take numerous forms, which primarily concern the following four areas: media, businesses and industries, technologies as well as content. (1) *Convergence of media* describes the combination of previously independent services, technologies and devices. As a result, new forms of communication emerge, including mobile Internet, mobile radio, Internet TV and Internet telephony. (2) *Convergence of businesses or industries* examines how firms or even whole industries are increasingly growing together, engaging in co-operations and collaborations that are located outside their original fields of expertise. While some projects are implemented lastingly, others are executed on a short-term basis. (3) *Convergence of technologies* presents the most commonly discussed form of convergence. It refers to technological devices that integrate numerous individual services, bundling them into a unified and standardized form as it is the case with Unified Communications or Unified Messaging. This implies that different communication forms (i.e. text messages, pictures, videos or emails) can be accessed by a variety of devices, such as tablet PCs or smartphones, regardless of the recipient's actual location. (4) *Convergence of content* means that data can be carried across diverse communication vehicles and used multiple times, yet not without implementing adaptions that match the specific requirements of each platform (Diehl *et al.*, 2013). Content convergence, for instance, is prominent in news agencies, where stories are broadcasted in the newspapers' print, online and mobile editions and, at times, even embedded as on online video stream or podcast (Karmasin and Winter, 2000).

Convergence's Increasing Relevance

According to Dennis (2003), convergence does not cover changes in technical/technological services and platforms alone, but also comprises altered business models and/or legal regulations, conditioned by the "blurring […] lines between media" (Pool, 1983, p. 24). Hence, convergence is also of relevance to areas outside of the media realm, where it impedes market deregulation tendencies, globalization, technical as well as technological innovation and altered customer expectations (Rhodes *et al.*, 2006). As such, the topic area fuels into numerous disciplines and academic areas of research, which will be briefly elaborated on in the next paragraphs.

Convergence and the Media

Convergence has had dramatic implications for the present-day media and communication landscape; its role is also not expected to diminish within the years to come as new technologies are developed on a regular basis. As the media drive these developments, the media industry is forced to adopt rather swiftly, whereby convergence's role is two-fold: on the one hand, the media sector has to deal with an over-expositional increase in communication vehicles, which have multiplied by virtue of the Internet's more dominant role and the rise of Internet-related services; on the other hand, dissolving boundaries between different industrial segments have a bearing too, forcing content-producing companies to broaden their professional horizons (Tambini, 2001). With content being nowadays, first and foremost, digitized, the Internet is the technology driving these developments; as the consequence, the media sector takes on characteristics similar to those of the IT sector (Noam, 2009). The challenges that this transformation poses particularly affect the sector's major agents: while media owners are confronted with altered workplace environments, staff requirements and content production/distribution routines (Ofcom, 2008), consumers are provided with the opportunity to use multiple platforms at once or switch freely between numerous channels, enabled through the integration of multiple functionalities into one single outlet (Ofcom, 2008).

Convergence and the Business Environment

In the business realm, convergence captures "the growing together of technologies, which fundamentally alters the boundaries of previously independent industry or market sectors and merges them into a new competitive environment" (Bally, 2005). As a result, market or industry definitions become more complicated, reducing the boundaries and activities that are unique to each sector (Lind, 2005; Bauer *et al.*, 2003): "Convergence between previously disjointed markets can be viewed as the erosion of boundaries that define and isolate industry-specific knowledge" (Pennings and Puranam, 2001, p. 3). Both technical and technological advances transform these industry environments, specifically in the areas of production and distribution, marketing and promotion as well as consumption. Blurring boundaries, thus, mark sectorial convergence which is "induced by converging value propositions, technologies and markets that lead to the emergence of inter-industry segments" (Bröring *et al.*, 2006, p. 487).

In the course of industry convergence, new and innovative products and services come into being, which benefit from overlapping industry segments: "As industry structures and boundaries become more permeable to the rising flow of innovations and new product concepts across different markets, these developments often mean that technologies commercialized in one industry could significantly influence, or even shape, the nature of product and process evolution in other industries" (Lei, 2000, p. 700). Alternative solutions and offerings then require innovative and Internet-driven business models; for organizations, work processes need to become more flexible and adaptive, embedded in as well as supported by online tools at the same time (Schwarz and Gustafsson, 2013).

Apart from industry structures and work routines, also organizational behavior is deemed to change. Conditioned by the rise of convergence devices like tablets and smartphones, communication and interaction patterns amongst the workforce experience a redefinition. Key terms in this area concern concepts like home office, work-life-balance, multi-tasking – all enabled by omnipresent (mobile) devices and advanced (online) storage capacities that permit employees to juggle personal needs and professional requirements. Yet, business owners and managers are burdened with ensuring that work is done properly and in time, even though their staff is splitting their working time between their homes and the actual office, bypassing constant supervision and control. Handling and dealing with these gadgets and environments, thus, requires a proper education and knowledge in a variety of areas (Zorn, 2011), whereby desirable skills particularly concern employees' abilities to deal with more flexible working environments, short-term team structures, technological knowledge and intercultural competencies (Diehl *et al.*, 2013).

Convergence and the Customer

Trends of convergence also affect media production and consumption practices. As part of content convergence, media offerings are used multiple times, meeting consumers respectively their personal needs along a multitude of platforms, both online and offline. This is enabled by advanced technological infrastructures, which have experienced a rapid growth, particularly in the areas of broadband Internet usage and mobile communication access (International Delphi Study, 2009), conditioned by the digitalization of content in form of online archives and multiplatform promotional strategies. Especially younger audiences are migrating online, selectively consuming content that is to their liking. As a result, convergence leads to divergence and fragmentation at the same time. It is important to note that convergence and divergence do not present contradictions but two ends of the same continuum (Pool, 1983; Jenkins, 2001): "As an analytical bracket, [convergence] bridges and integrates both different disciplinary discourses on media change and conflicting detailed processes of convergence and divergence as two sides of the same trend" (Latzer, 2013).

Media convergence has drastically altered media consumption practices as well, allowing for one-to-one, one-to-many and many-to-many interactions (Kadar and Könczei, 2014). With it, consumption has become more flexible, versatile (i.e. independent of device and location) and personal, with users getting what they want, when they want it and how they want it. New technologies also award former passive consumers the possibility to actively participate, design and personalize products respectively messages. Through the Internet, consumers are enabled and encouraged to contribute online, transform and edit media content (Zorn, 2011); they can even share it, since the Internet makes for "spreadable media" content (Jenkins *et al.*, 2013). In the process, the traditional producer/consumer dichotomy is dissolved as, nowadays, every user can simultaneously occupy the producer/sender and consumer/recipient role (Jenkins, 2013). Through convergence, amateurs are empowered (Kadar and Könczey, 2014); they become editors, freely selecting – and distributing – the news they are interested in via a variety of forms, all enabled by interactive communication technologies. This is the case for New age-media consumers are migratory, socially active, outspoken and publically connected (Jenkins, 2008).

As a result, technical background knowledge becomes key, especially in a technology-driven workplace environment (Zorn, 2011). Media managers or marketing executes havel to, therefore, be familiarized with how to appropriately prepare content to catch consumers' attention, as well as the frequency with which their consumers are directly targeted. As consumers are actively participating in the content-creation process – in form of user-generated content (UCG) – they also have to find ways of accommodating and rewarding consumers for their (positive) contributions; in the case of negative feedback or news, executives are confronted with how to appropriately respond to criticism as virtual word-of-mouth can lastingly damage a corporation and its image. Through their online engagements, consumers are capable of shaping and directing demand for products and brands (Jenkins *et al.*, 2013). Thus, these issues warrant to be addressed in an educational setting.

Convergent Journalism

One occupational group that has to bear most of the convergence-induced burden is the journalistic profession. Technological convergence has altered the journalistic work routine at its core, where it presents "some combination of technologies, products, staffs and geography amongst the previously distinct provinces of print, television and online media" (Singer, 2004, p. 3). Trends like cross-media storytelling, multichannel reporting, multiplatform publishing and cross-media coverage (Kaltenbrunner and Meier, 2013) are mentioned most frequently together with concepts like the integrated newsroom and citizen journalism, which has been recently substituted with the more prominent term social journalism. Regardless of which label is being used, the concept describes citizens "playing an active role in the process of collecting, reporting, analyzing and (distributing) news and information" (Bowman and Willis, 2003, p. 9). As such, it presents a form of networked journalism (van der Haak *et al.*, 2012), elevated through networks of grassroots communicators, whose duties entail mobilizing public opinions and giving voice to ordinary people (Jenkins *et al.*, 2013). As individuals are invited to broadcast and publish their own stories (Yusuf, 2009), the public sphere is being widened.

News consumption has not remained the same either. Present-day consumers receive and respond to news differently than they did only a few years ago, e.g., they share or comment on stories (Erdal, 2007). With coverage happening at the pulse of time, they also demand to be informed quicker, more regularly and simultaneously across platforms. Text alone will not do to grasp recipients' attention, it has to be supplemented with images respectively videos, which transport messages quicker than written information alone. One tool that facilitates rapid dissemination is Twitter, which allows users to broadcast their stories in a nutshell, with a maximum of 140 characters. Stories published thereon are identified by emotional recounts and an immediacy in coverage (Fiske, 1994) and, thus trigger affective responses in recipients: "Twitter makes us empathize. It makes us part of it. Even if it's just retweeting, you're aiding the goal that dissidents have always sought: the awareness that the outside world is paying attention" (Shirky, 2009). Twitter, hence, enables "participant voyeurism" (Forte, 2009).

With citizens taking up professional duties and news consumption becoming more fragmented, the journalistic profession is experiencing a redefinition. As voices are growing in the online world, work becomes less predictable and controllable. For this reason, media education is called upon to address these challenges and offer students appropriate tools as well as hands-on-training classes regarding how to deal with a "convergence of competencies" – skills that are nourished by knowledge from more than one academic background. As these challenges brought about by convergence need to be addressed in an educational setting, the study at hand wants to shed some light on this important development from an inter-disciplinary perspective.

Method

An in-depth analysis of online-content was meant to provide some insights as to whether universities in eight European countries (Austria, Germany, Great Britain, Ireland, Scotland, Slovenia, Switzerland and Wales) and the United States have already begun to address the topic area of convergence and its implications for present-day business practices in their educational programs. It was concerned with revealing the degree according to which post-secondary institutions have taken up this recent trend and are, thus, responding to the new requirements of convergence by offering degree programs which provide the kind of media education needed today and in the future. Its design was loosely based on a recent study by Sharp and Brumberger (2013), who explored business communication curricula in 50 top-ranked undergraduate business schools. As its orientation suggests, the study was limited to one pre-defined area of study and could be seen as a state-of-the-art representation; by contrast, the investigation outlined herein attempted to determine the current status of curricula in media and related disciplines before offering suggestions for future development and comparability.

Countries were selected if their programs were featured on an online study portal which aided (prospective) candidates in their search for suitable educational programs. As collecting programs presented an extensive endeavor, renowned study portals were browsed for suitable program offerings[11]. With the exception of the United States, every country scrutinized in this investigation provided one such portal; instead, a plain google-search was conducted for the U.S., a well-established and highly-skilled educational market. A search was conducted on the previously selected study portals by use of three key words (convergence, cross-media and multimedia). The hits were then taken as a starting point. In a first step, the information presented on the study portal was examined in detail; in a second step, the program's original website was consulted and coded along a previously developed scheme of analysis. For the present study, a total of 443 different degree programs from nine counties were explored in detail (see Figure 14). A detailed content analysis was conducted over a period of two consecutive months (July/August 2013: Germany, Austria, Switzerland, and the United States; February/March 2014: Slovenia, Ireland, Great Britain, Scotland, and Wales) to analyze if convergence already constituted a fixed component in universities educational programs and professional trainings.

The chapter explores educational programs offered by (publicly and privately owned) universities, universities of applied sciences as well as colleges on a Bachelor, Master and PhD level with the intention of unraveling inasmuch convergence is already a topic of interest in a connected world. With convergence leaving no area of life – both professional and private – unaffected, programs from diverse backgrounds were included, e.g., media communications, journalism, economics, management as well as technical sciences.

[11] Austria: www.studieren.at; Germany: www.studieren.de; Switzerland: www.studium-schweiz.ch; Slovenia: http://www.studij.si/; Ireland: http://www.educationinireland.com/en/What-can-I-study-/; Scotland: www.scottland.org/study-in-scottland; Wales: http://www.wales.com/en/content/cms/english/study/wales_universities/wales_universities.aspx; Great Britain: www.educationuk.org and www.studybritain.com.

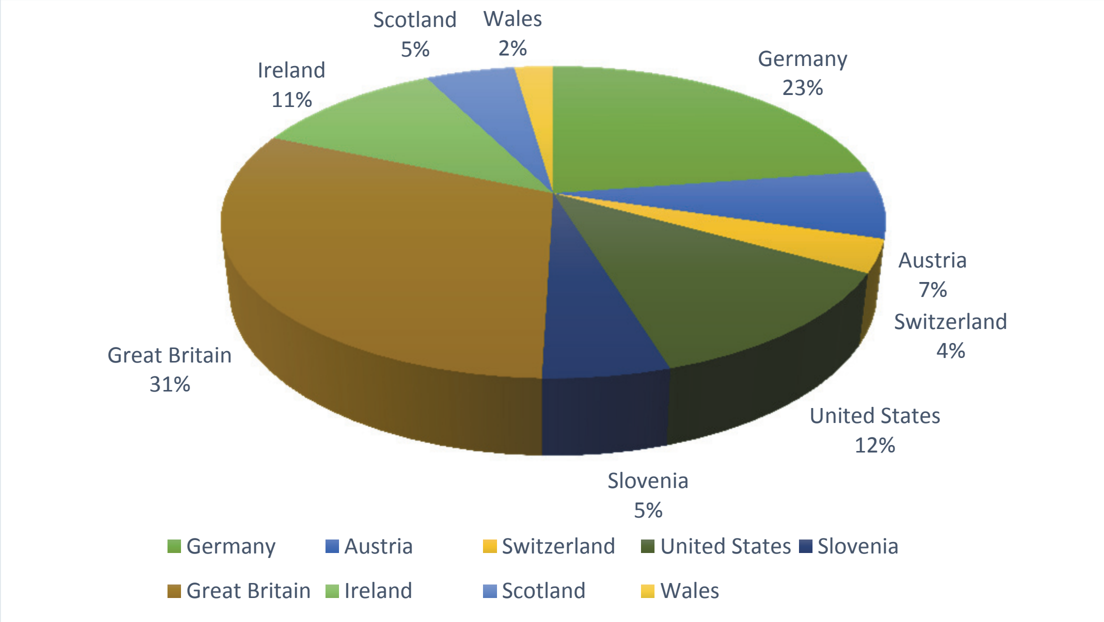

Figure 14: Number of Programs by Country (n=443)

Results

Results indicate that most of the 443 degree programs were predominantly offered by either public or private universities (67 %), followed by universities of applied sciences (16 %) and colleges (17 %). With regard to the programs' educational levels, the majority constituted Bachelor's degrees (55 %); Master's degrees ranked second (39 %) while doctoral/PhD programs made up the smallest segment (6 %). Even though the largest part of countries presented non-native speaking environments, a clear trend towards bilingual programs could be observed: more than two thirds of all programs (67 %) offered at least parts of their programs in English, paying tribute to a more globalized society and culturally 'converged' workplace settings, in which English has to be seen as a common denominator, a *lingua franca*. It also underlined the importance of a foreign language proficiency amongst students as future employees, who have to prove themselves increasingly in a multi-cultural work environment. This also means that programs offered in each country's native language are becoming less commonplace, the only exception being Slovenia, where classes were reportedly solely taught in Slovenian. Nonetheless, if demand increases for international staff, these programs might have to be adapted to changing global conditions. In terms of program format, most programs were still conceptualized as full-time studies, which have to be seen as a contraction to trends of convergence, which render working structures more flexible and unpredictable. This development would correspond rather with a part-time design that enables students to learn how to juggle the hardships of daily life with the ones encountered during internships or part-time jobs.

As convergence covers a wide range of subject areas, online content was searched for two other - related - concepts as well. *Cross-media* refers to the use of "more than one form of public communication" (Cambridge Dictionary, 2015) when communicating a message publicly. At times, it is seen as synonymous with trans-media and relies on a combination of formats (e.g., video, audio, and image) and channels (TV, radio, Internet, cinema, etc.; Phillips, 2012). Quite similarly conceptualized is the third term, *multimedia*, described as the "communicating or sharing [of] information in the form of sound, pictures, and video as well as text” (Cambridge Dictionary, 2015). Since the terms’ meanings do clearly overlap, they were seen as suitable for inclusion in the present study.

Out of the 443 degree program offerings, 38 % listed the term convergence (C), while cross-media (CM) was included in very few instances (9 %); multimedia, however, presented the most frequently used term (53 %), probably on grounds of its wide applicability. As actual program titles, neither convergence (7 %), cross-media (6 %) nor multimedia were frequently used, suggesting that they did not present programs’ sole foci yet. Convergence and cross-media were both used as module titles in 20 % of all occurrences in this category; multimedia constituted a module title in approximately one third (35 %) of all cases. All terms reached the highest score in the module content category, where convergence and cross-media were given in almost three quarters of all cases (73 % respectively 74 %); multimedia was included in slightly more than half of all modules (53 %). Example occurrences for each of the three terms are listed in Table 1.

Table 1: Example of Place of Listing.

Term	Use of Term	Category	University
Convergence	Media and Convergence Management	Study Title	Alpen-Adria-University Klagenfurt, Austria
	Convergence Journalism	Study Title	University of Missouri, United States
	Cross-media journalism and journalism in convergent media	Module	HMKW - Hochschule für Medien, Kommunikation und Wirtschaft, Berlin, Germany
	Integrating Media: Convergence in Practice (4)	Module	Penn State University, United States
	Media Literacy/Education – audiovisual culture and communication	Module Content	Otto von Guericke – University of Magdeburg
	Culture and Media Education	Module Content	University of Education Ludwigshafen
	New Media and Internet Technologies	Module Content	University of Bedfordshire, United Kingdom
Cross Media	Crossmedia Design and Development	Study Title	Danube University Krems, Austria
	Cross Media	Study Title	University of Applied Sciences Magdeburg, Germany
	Graphic Information Technology	Module Content	Arizona State University, United States
	Animation Design	Module Content	Istituto Europeo Di Design, Italy
	Digital Television and Interactive Media	Module Content	University of Greenwich, United Kingdom
	Applied Computer Science	Module Content	Otto-Firedrich University Bamberg, Germany
Multimedia	*Multimedia Journalism*	Study Title	University of Kent, United Kingdom
	Multimedia Journalism	Study Title	Teesside University, United Kingdom
	Multimedia Journalism	Study Title	Bournemouth University, United Kingdom
	Technical Communication	Module Content	Arizona State University, United States
	Telecommunications	Module Content	Indiana University, United States
	Journalism with New Media	Module Content	Cork Institute of Technology, Ireland

After having determined where the individual terms could be found, the content analysis deepened, further scrutinizing in detail how much attention the individual subjects received. Terms constituted course content to the largest extent (59 %), where they presented one specialized area. In fewer instances, full classes were reserved for one of the three specialized topic areas (36 %). Online content was further scrutinized in detail with the intention of working out where, where terms occurred, their place of listing. The term *convergence* was mentioned most frequently in the program description (57 %) and the course of study (25 %). Fewer mentions were noted in the course offerings (13 %), while the least occurrences were counted in the program curriculum (5 %). In the case of *cross-media*, the term was used to almost equal amounts in the program description (41 %) respectively the course of study (39 %); likewise, it was deployed to a lesser extent in both the course offerings (11 %) and the actual program curriculum (9 %). For *multimedia*, the same pattern could be observed: the term was mentioned most often in the program description (69 %), in the course of study (19 %), in the course offerings (11 %), with the least counts being noted for the curriculum (1 %).

Besides counting occurrences of the individual terms, online information was also surveyed in regards to how the individual terms were defined. This step was seen as vital to determine how the individual institutions comprehended these terms and used them to shape their course offerings accordingly. Generally, definitions were almost completely absent and only included in 1 % of all cases. For this reason, individual modules and classes were assigned to theoretical clusters to allocate them to selected academic fields. These were: media and communications, journalism, economics and management, as well as technical studies. Blurring boundaries in the academic field have led most programs' foci to shift, as only 29 % of all programs emphasized media and communications content alone. Overall, universities' willingness to broaden their academic horizons was noteworthy since almost equally high pronounced scores were allocated to the areas of journalism (25 %) and technical sciences (27 %). As it is especially the latter that is driving convergence developments, it is necessary for students to understand the forces that bring about new forms of convergence. This is particularly crucial for these are likely to factor into their future workplace settings as well. While economic and management aspects fall rather short (4 %), programs with interdisciplinary focus have begun to gain some ground, already accounting for 15 % (see Figure 15).

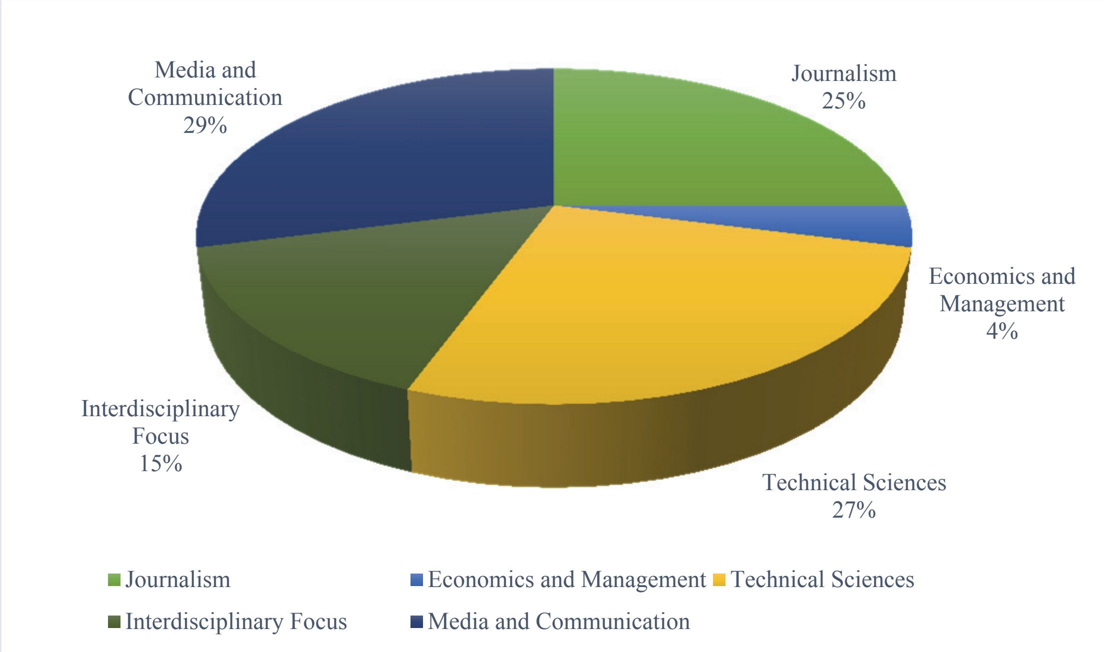

Figure 15: Program Focus (n=443)

In spite of programs being predominately conceptualized as full-time studies, they were not purely theoretical anymore. In all of the offerings explored, 44 % of classes contained both practical and theoretical elements; practical classes alone, however, could be hardly found (1 %). The rising number of applied classes allowed for the conclusion that knowledge application in a practical setting becomes inevitable, especially in the field of journalism, where most classes focused on cross-media promotion and multi-media production. Those new trends were integrated into the programs to varying extents as well, with most specializations being allocated a single class (63 %); in one third of all cases, they were even assigned a module, which consisted of 2 to 3 individual classes. Full degree programs in the area of convergence, cross-media and multimedia were scarce, amounting only for about 8 %.

Discussion of Results

The results brought about by the study at hand suggest that convergence (to a lesser extent) and related concepts (i.e. multimedia to a larger extent) have started to gain relevance in the media education realm, where the boundaries between academic disciplines are increasingly blurring and new, convergent (i.e. interdisciplinary) degree programs emerge. There is evidence that the three terms put to the test in the present paper are becoming relevant in the media education realm throughout Europe and in the United States. Of the three terms, multimedia was most commonly used (~ 53 %) and was preceded by convergence (~ 38 %); the clear last spot was occupied by cross-media (~ 9 %). Within the different educational programs, all terms were used in almost equal parts as module content (~ 65 %), module titles (~ 20 %) and study titles (~ 7 %). However, some country-specific differences became obvious: while the terms were mostly deployed as module content in all countries, they were more frequently used as study titles in the U.S. (24 %), which could hint at the increased importance attributed to convergence overseas (see Figure 16).

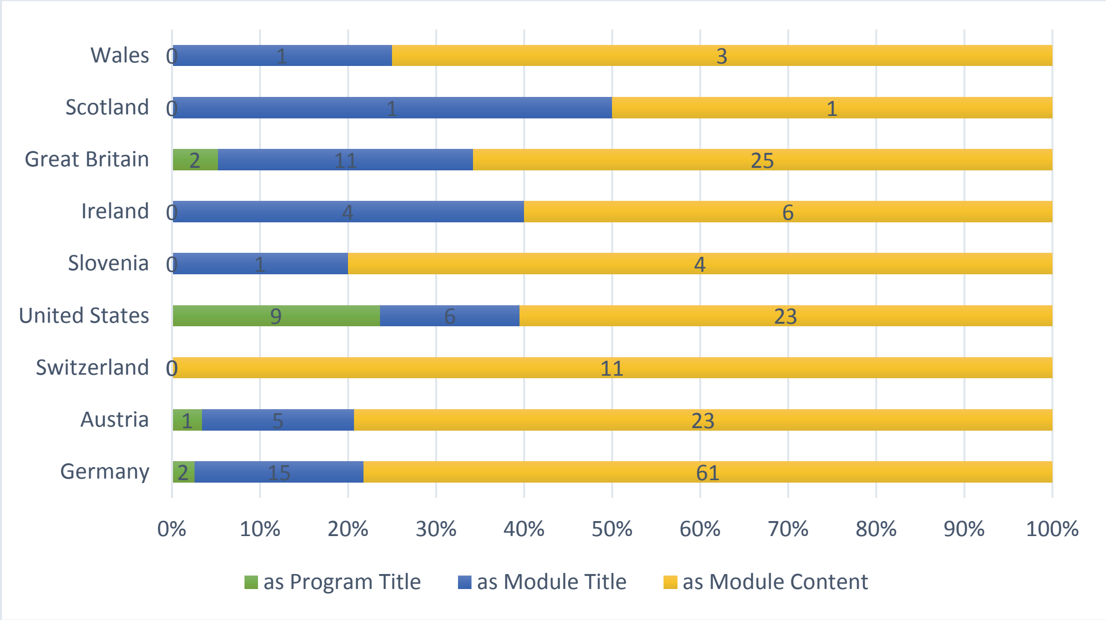

Figure 16: Extent of Specialization (n=443)

In terms of the degree programs' foci, an assumed tendency towards the area of communication could not be confirmed. While in some programs a clear focus on media and communications prevailed (29 %), journalistic topics (25 %) and technical studies (29 %) already went head-to-head. Combining media elements with concepts taken from economic and management as well as technical sciences, programs with interdisciplinary focus were (15 %) were unable to compete at this point (15 %); even less so were programs with a focus on economics and management (4 %). The amount of classes assigned to the topic areas seemed to be indicative of these results as well: in 63 % of all cases, single classes were dedicated towards one of the three subject areas, whereas one module was assigned in 29 %. Full degree did not constitute the norm yet, accounting for solely 8 %.

Recommendations and Future Outlook

Globalization is the key factor driving convergence and has led interdisciplinary and convergent management competencies to be put at the focus of present-day discussions (Ralston *et al.*, 1993; Ralston *et al.*, 1997). Even though demand is on the rise, these developments cannot be observed in the job market yet, as very few job advertisements (> 5 %) explicitly list convergence and related skills as a pre-requisite. An additional[12] survey of 400 job postings (both online and offline) between July and August 2013 in Austria only found a handful of job ads to list convergence (2 %) while multimedia was included slightly more frequently (8 %), especially in the IT and electronic sectors.

[12] In this study we analyzed the most important Austrian job postings portals and the two most important Austrian newspapers, Der Standard and Die Presse.

Yet, academic programs in the area of convergence, multimedia and cross media are mushrooming throughout the world. A survey of two international study portals that list renowned programs on both a Bachelor and Master level has produced the following results for 2014 and 2015[13], which indicate the area's increasing academic toll (Table 2):

Table 2: Occurrences of Convergence on International Study Portals

	www.BachelorsPortal.eu		www.MastersPortal.eu	
	2014	**2015**	**2014**	**2015**
Convergence	17	50	100	147
Cross-Media	71	193	125	190
Multimedia	185	606	319	496

Both academics and practitioners are familiar with the term convergence, which symbolizes "a rhetorical toll in order to facilitate reform, [with the] media landscape undergoing significant change" (Fagerjord and Storsul, 2007, p. 28). Convergence has disrupted traditional orders and some long-standing distinctions no longer prevail: individual communication vs. mass communication, public communication vs. private communication, message sender/producer vs. message recipient/consumer. Rather, these boundaries blur, resulting in new forms of communication and role types (Latzer, 2013). Due to convergence, the communication landscape gains in complexity, characterized by shorter technological life-cycles, new forms of innovation and production (Latzer, 2009; Latzer, 2013), and the Internet as a dynamic, complex and adaptive environment that invites users to participate in the content and product creation process. It is the Web 2.0 which equips them with new tools and, thus, increases the number of actors involved in the product development process (Bauer and Herder, 2009). Through convergence, amateurs are empowered (Kadar and Könczei, 2014): they become editors, freely selecting – and distributing – the news they are drawn to in a variety of forms, all enabled by the interactive nature of the Internet.

The forces driving convergence are the digitalization of content, as well as the globalization and the deregulation of communication (Latzer, 2013). As a consequence, the scope of the academic landscape has to change as well and allow for integrated media education program solutions, nourished by input from diverse yet connected disciplines. Without question, it is universities' duty to provide appropriate tailored educational programs that take present-day and future challenges into account. This means that university board members and educators must not solely emphasize the topic of convergence from a media and communications point of view but should also pay tribute to other trends, challenges and social developments – e.g., the transformation from an information society to a knowledge society, globalization as well as altered political and legal regulations – which require them to expand their academic programs to related areas (see Figure 17).

[13] The number of degree programs listed does not offer any indication of the extent each area occupies in the program; it simply suggests that the topic is featured therein.

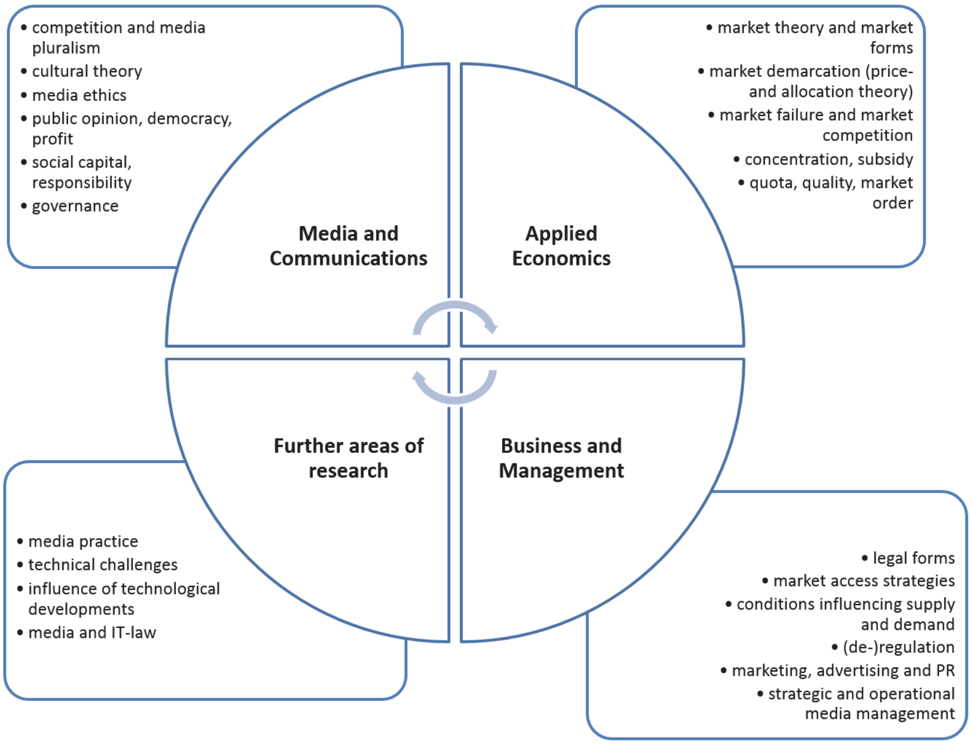

Figure 167: The broadening scope of Media Education (own illustration)

The present study was able to pinpoint that the lack of definitions of the core terms impeded the assessment of the subject area's exact focus. It is recommended to include definitions as they are able to provide some guidance and/or orientation to future students on what to expect from the actual program. In addition, the extent and amount of information available on each program should be put in a unified design and cohesive structure so that comparability is not hampered.

Trends of convergence are going to transform the educational landscape lastingly. Since they occur unpredictably, the above elaboration is far from being complete; it solely fits current workplace requirements but does not constitute a permanent or fixed solution. Rather, it tried to draw attention to already identified trends, which indicate that convergence increasingly dissolves academic boundaries and needs to be mirrored in future media education programs as such.

References

Allan, S. (2010). Series Editor's Foreword. In T. Dwyer (ed.). *Media Convergence*. Maidenhead: Open University Press. XIII-XIV.

Arnolds-Granlund, S.B.; Kotilainen, S. (2010). *Media Literacy Education: Nordic Perspectives*. Gothenborg: Nordicom.

Bally, N. (2005). *Deriving managerial implications from technological convergence along the innovation process*. Åbo: Åbo Academy School of Business.

Bauer, J. M. & Herder, P. M. (2009). Designing socio-technical systems. In A. Meijers (ed.), *Handbook of the philosophy of technology and engineering sciences*. (pp. 597-625). Amsterdam: Elsevier.

Bauer, J. M.; Vesperini, P.; Wildman, S. S. (2003). The state of telecommunications: realities, regulation, restructuring. *Michigan State DCL Law Review*. 3. 531-561.

Bowman, S. and Willis, C. (2003). *We Media: How audiences are shaping the future of news and information*. The Media Center of The American Press Institute. Retrieved 25 September 2015 from http://www.hypergene.net/wemedia/download/we_media.pdf

Bröring, S.; Coultier, L.M.; Leker, J. (2006). The front end of innovation in an era of industry convergence. *R&D Management*. 36(5). 487-498.

Cambridge Dictionary. (2015). Cross-media. Retrieved 25 September 2015 from http://dictionary.cambridge.org/dictionary/british/multimedia

Cambridge Dictionary. (2015). Multimedia. Retrieved 25 September 2015 from http://dictionary.cambridge.org/dictionary/business-english/cross-media

Dennis, E.E. (2003). Prospects for a big idea – Is there a future for convergence? *The International Journal on Media Management.* 5. 7-11.

Diehl, S.; Karmasin, M.; Leopold, A.; Koinig, I. (2013). New Competencies for the Future. In S. Diehl & M. Karmasin (eds.). *Media and Convergence Management*. (pp. 355-378). Berlin, Heidelberg: Springer.

Erdal, I.J. (2007). Researching Media Convergence and Crossmedia News Production: Mapping the field. *Nordicom Review*. 28(2). 51-61.

Fagerjord, A. & Storsul, T. (2007). Questioning convergence. In T. Storsul & D. Suedahl (eds.). *Ambivalence towards convergence: digitalization and media change*. Göteborg University: Nordicom.

Fiske, J. (1994). *Media Matters: Everyday Culture and Political Change*. University of Minneapolis: Minnesota Press.

Flew, T. (2008). *New Media: An Introduction*. 3rd edition. Oxford: Oxford University Press.

Forte, M. (2009). America's Iranian Twitter Revolution. In *Zero Anthropology*. 17 June 2009. Retrieved 25 September 2015 from http://zeroanthropology.net/2009/06/17/americas-iranian-twitter-revolution/

International Delphi Study. (2009). *Zukunft und Zukunftsfähigkeit der Informations- und Kommunikationstechnologien und Medien*. Retrieved 2 May 2015 from http://www.tns-infratest.com/presse/pdf/Zukunft_IKT/Zukunft_und_Zukunftsfaehigkeit_der_IKT_2009.pdf

Jenkins, H. (2001). Convergence? I diverge. In *Technology Review*. June 2001. 93.

Jenkins, H. (2006). *Convergence Culture: Where Old and New Media Collide*. New York, London: New York University Press.

Jenkins, H.; Ford, S.; Green, J. (2013). *Spreadable Media: Creating Value and Meaning in a Networked Culture*. New York, London: New York University Press.

Jenkins, H. (2008). *Convergence Culture: Where Old and New Media Collide*. 2nd ed. New York, London: New York University Press.

Kadar, M. & Könczei, Z. (2014). The Content Management of Media Convergence. In *Journal of Media Research*. 7(3). 25.

Kaltenbrunner, A. & Meier, K. (2013). Convergent Journalism – Newsroom, Routines, Job Profiles and Training. In S. Diehl and M. Karmasin (eds.). *Media and Convergence Management*. (pp. 285-298). Berlin, Heidelberg: Springer.

Karmasin, M. & Winter, C. (eds.) (2000). *Grundlagen des Medienmanagements*. Munich: UTB.

Latzer, M. (1997). *Mediamatik: Die Konvergenz von Telekommunikation, Computer und Rundfunk*. Opladen: VS.

Latzer, M. (2009). Convergence Revisited: Toward a Modified Pattern of Communications Governance. In *Convergence*. 15(4). 411-426.

Latzer, M. (2013). Media Convergence. In R. Towse, R. & Handke, C. (eds.). *Handbook of the Digital Creative Economy*. (pp. 123-133). Cheltenham: Edward Elgar.

Lei, D.T. (2000). Industry evolution and competence development: the imperatives of technological convergence. In *International Journal of Technology Management*. 19(7-8). 699-738.

Lind, J. (2005). Ubiquitous convergence: market redefinitions generated by technological change and the industry life cycle. In *Proceedings of the DRUID Academy Winter 2005 Conference*. Skorping, Denmark.

McPhillips, S. & Merlo, O. (2008). Media convergence and the evolving media business model. *The Marketing Review*. 8(3). 3. 237-253.

Merriam Webster. (2015). *Convergence*. Retrieved 25 September 2015 from http://www.merriam-webster.com/dictionary/convergence

Noam, E.M. (2009). *Media ownership and concentration in America*. Oxford: Oxford University Press.

Ofcom, (2008). *The International Communications Market 2008. Convergence*. December. London: Ofcom.

Oxford Dictionary. (2015). Digitization. Retrieved 25 September 2015 from http://www.oxforddictionaries.com/de/definition/englisch_usa/digitization

Pennings, J.M. and Puranam, P. (2001). Market convergence and firm strategy: new directions for theory and research. *In ECIS Conference: The Future of Innovation Studies*. Eindhofen, The Netherlands.

Perez Tornero, J.M.; Jacquinot-Delaunay, G.; Tayie, S.; Carlsson, U. (2008). *Empowerment Through Media Education.* Gothenborg: Nordicom.

Phillips, A. (2012). *A Creator's Guide to Transmedia Storytelling: How to Captivate and Engage Audiences Across Multiple Platforms*. New York: McGraw-Hill Professional.

Pool, I.d.S. (1983). *Technologies of Freedom*. Cambridge, MA: Harvard University Press.

Ralston, D.A.; Gustafson, D.J.; Cheung, F.; Terpstra, R.H. (1993). Differences in Managerial Values: A Study of U.S., Hong Kong and Prc Managers. In *Journal of International Business Studies*. 24(2). 249-275.

Ralston, D.A.; Holt, D.H.; Terpstra, R.H.; Yu, K.-C. (1997). The Impact of National Culture and Economic Ideology on Managerial Work Values: A Study of the United States, Russia, Japan, and China. In *Journal of International Business Studies.* 28(1). 177-207.

Rhodes, J., Walsh, P.; Lok, P. (2006). *Convergence and Divergence Issues in Strategic Management.* Retrieved 26 August 2013 from http://w3.unisa.edu.au/igsb/docs/wp-lok1.pdf

Schwarz, E. & Gustafsson, V. (2013). Business Modelling and Convergence. In S. Diehl and M. Karmasin (eds.). In *Media and Convergence Management*. (pp. 9-24). Berlin, Heidelberg: Springer.

Sharp, M.R. & Brumberger, E.R. (2013). Business Communication Curricula Today: Revisiting the Top 50 Undergraduate Business Schools. In *Business and Professional Communication Quarterly*. 76(1). 5-27.

Shirky, C. (2009). *Q&A with Clay Shirky on Twitter in Iran*. TED Blog. 16 June 2009. Retrieved 25 September 2015 from http://blog.ted.com/qa_with_clay_sh/

Singer, J. (2004). Strange Bedfellows? The Diffusion of Convergence in Four News Organizations. *Journalism Studies*. 5(1). 3-18.

Storsul, T. & Fagerjord, A. (2008). Digitization and media convergence. In W. Donsbach (ed.). *The International Encyclopedia of Communication*. Oxford: Wiley-Blackwell.

Tambini, D. (2001). *Revolution, Communication and Reform*. London: Institute for Public Policy Research.

Van der Haak, B.; Parks, M.; Castells, M. (2012). The Future of Journalism: Networked Journalism. In *International Journal of Communication*. Vol 6. 2923-2938.

Wirth, M.O. (2006). Issues in media convergence. In A.B. Albarran; S.Chan-Olmsted; M.O. Wirth (eds.). *Handbook of Media Management and Economics*. (pp. 445-462). Mahwah, NJ: Lawrence Erlbaum.

Wirtz, B.W. (2011). *Media and Internet Management*. Wiesbaden: Gabler.

Yusuf, H. (2009). Old and new Media: Converging during the Pakistan Emergency (March 2007-February 2008). Center for Future Civic Media. 12 January 209. Retrieved 25. September 2015 from https://civic.mit.edu/blog/humayusuf/old-and-new-media-converging-during-the-pakistan-emergency-march-2007-february-2008

Zorn, I. (2011). Medienkompetenz und Medienbildung mit Fokus auf Digitale Medien. In H. Moser; P. Grell & H. Niesyto (eds.). *Medienbildung und Medienkompetenz*. (pp. 175-209). Munich: Kopaed.

Chapter 18

A formative approach to the relation of the university to companies: Beyond obtaining resources

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Abstract: In Mexico the linking of universities to companies has traditionally being intended to obtain resources and little attention has been given to its formative dimension. The relation university-companies has been renewed at the Faculty of Mechanics and Electric Engineering to foster the formative contribution of professional practice. Nevertheless, as a dynamic and multifactorial process, it requires permanent monitoring and improvement of students' training. This chapter is aimed at analyzing the effect of linking university faculties to companies on the education of would-be engineers. The findings include the foundations and assessment of the *formative approach* resulting from a theoretical inquire and gathering opinions of professors, students and managers by means of interviews and other techniques. Likewise, several samples of effective linking activities are shown, though some of them might need to be perfected to suit the requirements of a different context. The study proved that a comprehensive strategy oriented to the students' education is needed to influence upon social development.

Keywords: *formative approach*, linking process; education of engineers

Introduction

The main social responsibility of the university is the training of the students with human high values and a comprehensive education that allows them to be agents of changes and development once graduated.

Now-a-day the international context is subjected to rapid and constant changes that require a significant transformation of Higher Education vision and priorities. Consequently, one of its fundamental objectives is the education of students to meet new challenges. The opportunities for setting relations between the university institutions and the socio-economic environment are numerous and varied, such relations are expected to promote the training of engineers to face the demands of society.

Castillo, Treviño and Reynoso (2013) express that Mexico is located in the 66th position among 139 compared economies and highlight that even though linking efforts are difficult in the country, the scientific-technological conditions of the state of New León offer many opportunities. For this reason, the Faculty of Mechanics and Electric Engineering (FMEE) is confronting the important challenge of achieving an effective linking with the industrial sector.

Mexican universities, and in particular the "Universidad Autónoma de Nuevo León" has kept a permanent contact with companies to join efforts in attaining the fulfillment of their main functions. Nevertheless, a lack of clarity and general consensus in relation to the links between universities and companies is still present. The need to face such problem demands going beyond obtaining profits and resources by giving priority to the formative dimension.

Castillo and Cols (2013) consider that the resources generated by the diverse models or linking means should be used in the universities to assist the necessities that contribute to their mission. However, the general practice indicates that the economic criterion prevails and the formative potentials of students' involvement in production are currently underestimated.

The authors agreed with Zayas (2011) in considering that managers are not given priority to the linking process, they regard it as the sole responsibility of universities, and even believe that the government and the schools should provide funds to companies to support the students training there.

At the present time it is urgent a closer interaction of the universities with the environment. Although this is not something new, the reality indicates that this interaction requires not only to be recognized but to be renewed as well. The topic has been widely studied; however there is a clear need for a larger improvement. Campos and Sánchez (2005) sustain that the linking between the Latin American university and its respective productive environments is a task that is still to be accomplished.

The linking activity, like other university process, has been constantly developing, but the results are still below the requirements. The students could only become "agents for a change" if they have a strong implication with the university surroundings. They might be able to transform only what they really know.

As Antúnez has expressed, *"the university has several missions, one of them accounts for social behavior and the whole academic institution (professors, students, managers and administrator) relations with the community"* (2011, p. 208). At the same time, one should remember that the main social function of the university is to provide society with graduates characterized by ethical high values resulting from their comprehensive education. Students are expected to change the environment and keep personal development once they enter into labor activity. This is only possible through teaching and learning, academic research, and particularly by means of linking process with the socio-economic environment.

There are several experiences that impact in the formation of the engineering student, an example is showing by Jiménez, Díaz and Lloret (2004), where teaches a plan for the integral development with the use of corporate networks. Show a practical and real case of integration of e-learning in the training of workers in an enterprise. Minimizing the impact that suppose the carrying out of a longer course in high technologies, but looking for the highest performance in the student learning.

Consequently the strengthening of formative actions in the linking process is needed. The solution might be to introduce a formative approach *that develops the orientation of the linking process toward student's education both as citizen and professionals.* Following these ideas, this chapter is aimed at analyzing the potentials of the linking process for the training of students, aside from the economic resources it eventually produces. The findings, resulting from a research project of the Faculty of Mechanics and Electric Engineering, include the foundations of the formative approach to the university and the companies linking process.

During the first decade of the XXI century the topic of the linking of the university to the company has been the object of discussion in forums with increasingly frequency, the topic has become an important aspect of the higher education calendar. However, (Martínez, 2000) describes a tendency to reduce the linking process to the relation of the university with the productive sector of society, without taking into account how it impacts in a precise way in the education of the would-be engineers.

The conception of the National Association of Institutions of Higher Education (ANUIES) shows a transcendent appreciation of the linking process by understanding such relations of university institutions with the productive sectors as a mechanism to positively contribute to education and upgrading students and scholars in facing local, regional and national problems. This conception favors the pedagogic training of the university staff, the innovation and improvement of the processes that take place in both places, as well as the effective insertion of students in the cultural community life (ANUIES, 2000).

There are evidences of implementations of several linking models with the productive sectors in Mexico. Nevertheless, these models are usually copycats of those devise for the North American context, in such a way that the obtained results are far from the level of success achieved in North American universities, operating high budgets derived from the linking to companies or foundations (Arocena and Sutz, 2001). This reality indicates the necessity to outline alternatives suited to the national context which will naturally allow giving an answer to social requirements in each moment.

It is known that the management of the linking with the company brings many advantages for the training of engineering students. Organizational changes in companies according to Lucena (2006) may allow a proposed curriculum to help students to prepare for complex engineering work experiences in the ever-changing organizations.

The modern social and professionals demands are challenging the design of the curriculum of universities studies in all branches of sciences, namely in engineering and technology. Hence, the authors agree with the idea of (Shigwara, 2014) that raising the university education demands an integrate and interactive system with the transformational governorship and leadership.

The linking process is frequently conceived as a way for getting mutual benefits for the company and the university, as a way for finding financial support to university process leading to subordinate projects to company interests and distracting the attention from the formative process.

In this way, the impact from this formative process is one of some variables said by Sakthivel (2007), Sakthivel shows the relationship between a number of variables related to the linking of total quality management (TQM) and their correlation with the overall excellence of Engineering Education (EEO).

To go step further the linking process conception has to be renewed. Consequently, the authors of this paper has defined it as a net of relationships between the university, the government, the company and the society to coordinate efforts for common benefits allowing to favor the formative process of the students, as well as obtaining resources through different coordinated projects under the leadership of the *university.* This definition subsumes former models of the linking process but at the same time excel them for its students-centered-approach, the priority given to the formative process and the leading role of the university in society. The proposed model corresponds to the already mentioned formative approach.

Methods

The population under study was made up of company professionals, and university professors and students belonging to the Faculty of Mechanics and Electric Engineering of the "Universidad Autónoma de Nuevo León". The sample includes only agents involved in the linking process, organized in representative and proportional strata, on intentional bases corresponding to the regional context and the relations set among the different agents. In selecting the size of the sample ("n") the following equation was used.

$$n = \frac{NZ_{\alpha}^{2} pq}{d^{2}(N-1) + Z_{\alpha}^{2} pq}$$

Where

N = Size of the sample.

Z = Trust level.

P = Success probability, or expected proportion.

Q = Failure probability.

D = Precision, (margin of proportional error).

The population comprises 689 students, 518 university professors, 64 university officials and 120 company managers, making a total of 1389. The sample includes a total of 123 subjects corresponding to the same categories (62 students, 26 professors, 10 university officials and 25 company personnel.

The interviews and surveys to evaluate the issue were accomplished in March 2013, in meeting rooms at the Faculty of Mechanics and Electric Engineering.

Quantitative and qualitative methodologies were combined in doing the research, in a range going from statistical procedures to essay writing technique. Data arrangement was facilitated by setting four categories related to the linking process that influence the formative dimension in one way or another. These categories are the following;

Category 1: Interrelation level of the agents in the linking process.

Category 2: Level of recognition of the linking process significance in students' education.

Category 3: Level of satisfaction of different agents.

Category 4: Level of contribution of different agents to the linking process.

Results and Discussion

The state of art of the linking process at the Faculty of Mechanics and Electric Engineering

Category 1: Interrelation level of the agent in the linking process.

The following is a description of the information gathered by means of the interviews given to each group of subjects.

The level of interrelation between the Faculty of Mechanics and Electric Engineering and companies (Table 1) was regarded as “high” by the majority of the subjects, 88.9% of professors graded it as high, 62.9% of students give the same answer, but 50% of companies personnel valued it only as average. Apparently, these findings are satisfactory and suppose there is an area of opportunities for the interrelation of agents. However, it seems recommendable to monitor the criteria of companies permanently.

Table 1. Valuation of interrelation level between agents of the linking process

Agents	*High*	*Average*	*Low*
Professors	88.9 %	11.1 %	-
Students	62.9 %	32.3 %	4.8 %
Managers	45 %	50.0 %	5 %

Category 2: Interrelation level of recognition of the linking process significance in students' education

To go deeper into the evaluation of the level of recognition of the linking process significance, managers and professors were asked to write an essay under the title "Present and future of the linking of the university to the companies". Most of those implied in the technique carried out a favorable valuation about the importance of the linking, they also manifested critical judgment on what the linking process should be.

The most representative expressions of managers were the following: 1) "The linking process is very important for all and we should promote a higher level of participation.” 2) "Society will be more capable of facing its problems if the interrelation between university and companies were perfected.” 3) “The linking process might be a source of social and economic initiative to increase the quality of life.” 4) “The linking process should be more clear, tenacious and effective to achieve better results". 5) “To fulfill the objectives innovative technology should be introduced in the linking process”. 6) “The lack of systematic arrangement should be avoided in the linking process.

On the part of professors the most interesting opinions were the following: 1) “Innovation in any service should surpass the triple propeller model”. 2) “The linking process should be regarded as an important function to be developed at the university”. 3) “A definition of joint working criteria should lead to the synergy of different levels”.

Category 3: Level of satisfaction of different agents

An important aspect to value the current state of this category is knowing the degree of students' satisfaction in relation to the linking process. The findings are shown in table 2. Professors, and students are included at the average level of satisfaction (55.6% and 53.2% respectively), whereas 65% of managers presents a low level of satisfaction.

Table 2. Agents satisfaction in relation to the linking process

Agents	*Satisfy*	*Half-satisfy*	*Low-satisfaction*
Professors	55.6%,	32.3 %	12.1 %
Students	53.2%	40.3 %	6.5 %
Managers	25 %	10 %	65%

Category 4: Level of contribution of different agents to the linking process

The finding shows there are difficulties in the enrollment of different actors in the linking process. Almost a half (48.4%) of the students consider their participation is low. On the contrary, approximately the same proportion (45%) of managers qualify it as average; whereas a large part of the professors (66.7%) consider their participation is high. Nevertheless, this result should rather be interpreted as an aspiration; in practice, professors show little interest for the linking process. This result make contrast with the real framework.

A formative approach to the linking process

The analysis of the antecedents and the gathering of data just discussed contributed to the construction of a framework and a new model of the linking process for the Faculty of Mechanics and Electric Engineering. The management of the linking process should be aimed at the education of engineer students, without disregarding other objectives and functions. As it is described in figure 1, the linking process has two fundamental focuses: the first one is the students' enrollment in social development; it includes innovation, research, social projects and community service all intended to favor the second focus: the students' personal and professional competence development. The dynamic of the relationship between them depends on the potentials and necessities of each of the agents involved in the process of linking. The proposed model takes the formative function as the central focus or main function. According to this model, linking is more than getting profitable resources; it is a key element in the formative process, connecting theoretical instruction with professional practice. The students' enrollment in social activities and real technological problem solution is instrumental; it is a mediating process for professional competence development and labor training that fosters an innovative capacity to face new challenging problems in the productive process of companies.

Figure 1 contributes to a general vision of the linking process. The formative process makes emphasis on the participation in the social development, the development of personal and professional competencies and the preparation for the future labor context, taking into account several objectives shown in the figure.

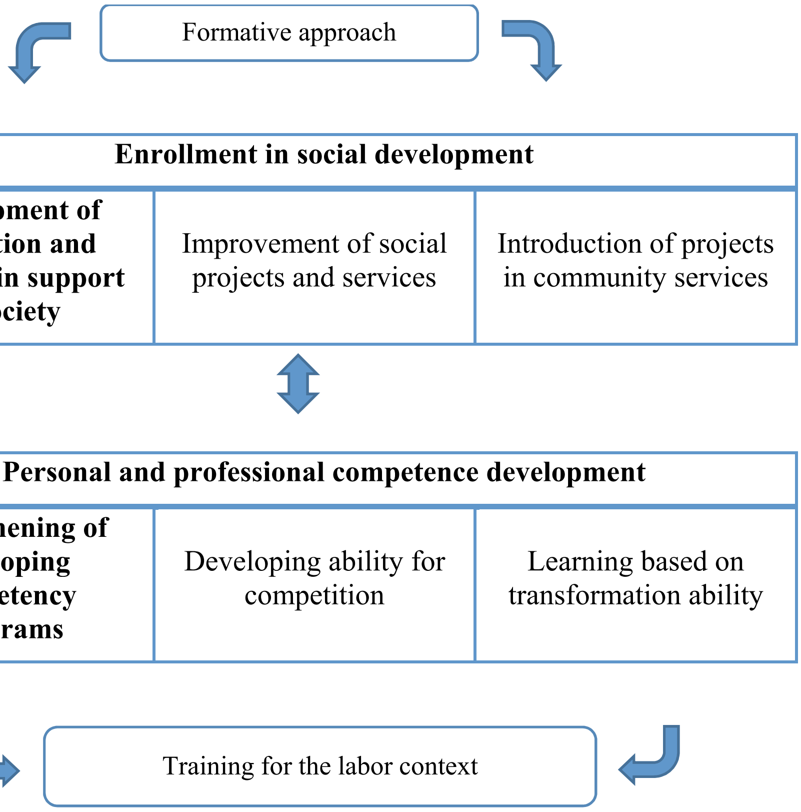

Figure 1. The formative approach of the linking process (Castillo, Álvarez, Cúpich, 2014)

Those approaches related to obtaining results, or traditional models of linking, include a number of objectives that contribute to students' education in one form or another, as well as to other processes that are related with it. However, as it has been previously explained that little attention is given to its educative potentials.

Finally those approaches take part of a case study model, and the most important results will be able to share in a short period of time.

The linking process as way of obtaining resources

The foundations of the formative approach constitute a theoretical platform for designing strategies to carry out the linking process and pursuing definite objectives. The general practice proved that the process is usually performed following certain routinized actions and patterns. Additionally the agents tend to be only partially involved. This is clearly expressed when surveyed agents declared that their enrollment is insufficient.

It is widely known that the linking process is a way of obtaining resources for the development of the university. These resources are beneficial to the infrastructure, the professors' staff and the students. These resources are usually invested in the creation or improvement of facilities, in updating technology, creating new academic areas, carrying out new research projects, developing programs for professors' development, offering scholarships, creating social services for the students and other incentives programs for the staff.

Illustration of linking activities for the student's enrollment in environmental professional transformation

The Faculty of Mechanics and Electric Engineering is one of the largest engineering faculties in Mexico. Around 15000 students are currently doing their bachelor degree in ten engineering majors: Engineer Administrator of Systems, Engineer Administrating Mechanic, Engineer Electrical Mechanic, Engineer in Electronic and Automation, Engineer in Electronic and Communications, Engineer in Materials, Engineer in Manufacturing, Engineer in Mechatronics, Engineer in Aeronautics and Engineer in Technology of Software. Some others are involved in postgraduate education in the above mentioned fields.

The university managerial structure includes a vice-director responsible for a wide range of the linking activities organized in the areas of interest related below.

1. Public relations.
2. Image and advertising.
3. Social and managerial services.
4. Language learning center.
5. Conventions
6. Industrial services.
7. Social relation services and events.
8. Continuing education.
9. Business projects.

These areas contribute to encourage the student's content with the environment. Linking meetings, professional conventions, academic projects linked to practice, social service, professional practices, labor pool and worker recruitments in campus, graduate monitoring, research projects, advising services, qualifying courses and continuous education, technological innovation parks and community services are among linking alternatives.

Linking meetings

These meetings are held following the objective or setting relations with the public and private sectors taking advantage of the strength of both sectors and establishing and stimulating cooperative relations that allow satisfying the needs of companies and the university. One of the most outstanding actions is the identification of possible way of enrollment for the students in activities tailored according the corresponding major of the participants.

The ordinary procedure is the signature of agreements between companies, the university and the local government. This will naturally have an impact in generating resources, social services and the opening of spaces in peer universities and institutions as well as contributing to the student´s training.

Numerous linking projects have been developed with funds provided by the government to support small companies with the help of the National Council of Science and Technology, the Program of Technological Innovation for the Competitiveness, the Program for Development and Innovation in Technology Precursors and the Program Support to the Technological Innovation of High Added

Value. These actions allow raising funds up to 52, 779,210.95 Mexican pesos in the academic period 2012-2013. Notice that *linking meetings* resulted in enlarging the potentials to offer solutions and answers to company problems by means of scientific research and technological development.

Professional conventions

Professional conventions are held to discuss different topics. Those related to comprehensive education are aimed at intensifying students' motivation and commitment to get knowledge and transform the environment. These conventions usually approached topics of social interest, personal professional development and society current problems and perspectives. Likewise, the general program of the convention included the participation of well-known lecturers reporting on case studies of successful professional performances on a wide range of fields and labor environment.

A particular innovative type of convention has been those related to the generation of knowledge. These conventions are intended to consolidate the graduates' and students' general background, both in relation to theoretical and practical knowledge of the labor world in particular majors and branches of engineering (Electric, Mechanics, Mechatronics, Materials, Systems, etc.). The corresponding lectures and workshops were delivered or guided by specialist that had earned managerial recognition in local region, all over the country or even in the international arena.

According to the mentioned objectives and in collaboration with associations and companies of the region, other academic, sport, cultural, social events were carried out. These events has led to the signature of agreements, or the organization of seminars, congresses, forums and symposiums involving the participation of students and professors of the ten faculty majors.

Academic projects linked to practice

The academic projects were linked to practice in an effort to aim at providing professional experience related to the different majors by means of training and developing professional competencies in the real labor environment. Once the trainee were in contact with real labor atmosphere and asked to solve real professional problems, they were not only high motivated but capable of identifying strengths and weaknesses in the productive process. This kind of activity anticipates the professional performance the would-be engineers will normally be facing in the near future.

These projects enlarged the participants' capacity by combining traditional professional practice with carrying out academic projects in the final semesters of each discipline. These projects were also associated to pursuing several specific objectives. The following were among them:

- To favor the student's comprehensive education by contrasting theoretical knowledge and the practical activity based on the professional reality.
- To develop competencies to diagnose, to draft, to evaluate and to intervene in the solution of problems or situations that the particular field engineering performance require.
- To gather information for improving syllabus and study programs.
- To enlarge the linking of FMEE with the social and productive environment.

The academic projects were carried out in teams of three to five students selected on the basis of each particular company needs. Those students were doing the final semester in disciplines that normally included the completion of research projects. In turn, these students normally followed an outline of professional practice; the company enables them as practitioners with the economic corresponding retribution. This outline includes the participation of professors, managers and professionals of the sphere of the services in an interrelated way. The lists of the participants appear in figures 2.

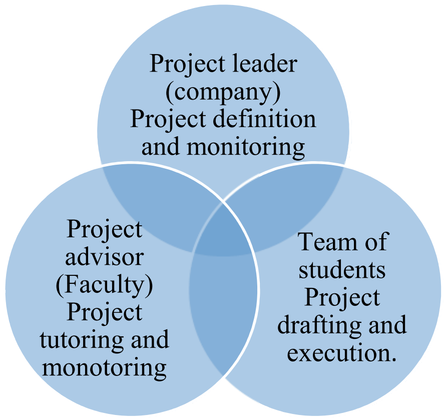

Figure 2. Role of the academic projects linked to practice participants

Social service

Social service was thought of to organize the contribution to the society on the part of the students. It was planned by the faculty staff and presupposed the coordination of efforts with public and/or private organisms that share objectives and vocational feelings of service.

The office for coordination of managerial service plans the actions with those companies that have previously signed agreements with the Faculty. This plan of actions included, among other objectives, the performance of professional practice and social service activities. Companies were asked to apply for the participation of students they really needed. This application turns into a feedback mechanism for the major staff to evaluate the grade of acceptance of the students. The selection of the students was the starting point for planning social services satisfying both companies and society demands and training needs of the major.

Initially this professional practice and the social service seemed to represent an extra load for the students. However, they proved to be a necessary component for their comprehensive education. Both services were an excellent way to link the students with the productive sector, with services and the enrollment in research and developmental projects. These alternatives of linking the students to the environment favored the acquisition of professional experiences, enriched the curriculum and constituted a high-priority aspect in the applications of the companies for graduates. The experience indicates that the evaluation companies normally do of trainees' performance during the period of professional practice and social service opens opportunities of employment for the would-be engineer once he graduates.

Professional practice

Professional practice is a key element for a comprehensive formative process, its main objective is to insert the students in the productive sector for the completion of tasks and functions characteristic of the profession contributing to the development of the professional competitions required in the different areas.

The professional practice monitored for the present study was characterized as follows:

- The student's activities at the public or privative productive sectors lasted 480 hours (6 months).
- The students were granted 15 credits.
- The first activities started during the 5th semester.
- The activities to be developed were planned in advanced and fully described in the agreement with the managerial sectors and of services

This professional practice differs from the practical activities the students are doing as *academic projects linked to practice.* The former demands the setting of specific rather large periods in permanence at the labor institution and allow the students to participate fully and directly in the productive process.

The results of the professional practice under control were very satisfactory in relation to students' development and competence training, however, there is a clear need of strengthening the faculty leadership in its links to companies, particularly to achieve a better understanding on the part of the employer of the importance of professional practice for the comprehensive education of the future engineer.

Labor pool and worker recruitments in campus

The labor pool is intended to create a relationship of students and graduates with the productive sector, and vice versa, by means of alternatives of employment search on the part of the students and job offers to work at different sectors. A considerable part of students combines the studies with a part-time job what allows them to acquire professional experiences, to enlarge the professional training and specific professional abilities by relating theory to practice and to get resources to self-finance its studies at the university.

The Faculty keeps an updated on-line labor pool where last semester students and graduates got in touch with job offers and found employment there. Additionally employment fairs are held twice a year with the participation of representatives of the different companies who make their job offers, interview candidates and eventually hire students and graduates.

Workers recruitments in campus are aimed at establishing a direct link between the students and graduates and human resources officials of the public and private productive sectors within campus facilities.

It was possible to establish a statistically correlation between students professional practice at a particular company and the employment offers once they graduated from college. That is, students that completed a professional practice period at a given company usually received an employment offer in that same company and usually got promotions accordingly to their professional performance.

Graduates monitoring

Once the students are graduated they are monitored by the Faculty staff, the objective of this monitoring is to get a permanent feedback by evaluating the graduates' performance and their professional abilities, and this allows collecting information for making decision regarding graduates' needs for updating and making the necessary arrangement in the curriculum of undergraduates. Additionally, it keeps the graduates contact with the university and encourage them to take part in continuing education.

Furthermore, this contact with graduates provides valuable information related to the time elapse between graduation and their first full employment, degree of satisfaction of employers and employees, remuneration rates, and correspondence between the study they have completed and technical requisites of the job given. This way the faculty staff may appraise how pertinent the curriculum is. In the study of reference, no significant differences between the ten majors were found in considering these variables.

The faculty staff is still working in perfecting the monitoring procedures by means of an all-inclusive management seeking for information both on the part of graduates and employers. This procedures allows not only to measure the quality of the process but to strength the formative functions of graduates, undergraduates, freshmen and those willing to major in engineering (Ancira, 2014).

Research projects

Research projects are a common type of task in university instruction; they are frequently associated to the content of technical subjects and directed to the solution of real technological problems. However, to meet the requisite of the formative approach to linking it is necessary to rethink its objectives. The authors' proposal includes: a) to consolidate the bonds to carry out specific projects and agreements of collaboration with the public and private sectors, b) to relate the study content with the surrounding reality. Through these projects the students consolidate their professional competence and contribute to the solutions of high-priority problems of national, regional and local development.

In all majors studied at the FMEE, there are courses closing with a research project developing professional competence to transform the environment by means of the solution of practical problems by means of the extensive application of the scientific method. These projects usually lead to the presentation of dissertations as the final evaluation of the major.

Advising services

The *advising service* was created in 2000 as systemic program of tutorships. The students are accompanied throughout their university studies by different mediating tutorship types. Freshmen are provided with inductive tutoring; sophomores and other medial year students are guided by a major tutor and advisors; whereas 5th students are helped by graduation tutors.

Tutoring is closely linked to the academic project and professional practice at the companies and its purpose is to offer to the public and private and integral solutions that allow the improvement of the management and the managerial practices with the highest quality.

Qualifying courses and continuous education

The objective of these courses is to enlarge and upgrade the knowledge of the personnel of the productive and social sectors. The courses are always designed on the basis of the target sector and have earned the recognitions of participants for achieving high quality standards. Undergraduates may enroll in these courses and complete them together with the curriculum of the major there are doing.

Technological innovation parks

The objective of this alternative is to influence upon the local socio-economic development. They are oriented to the technological development of regional companies by means of research projects and other university technical services. One of the most frequent activities is the training and updating or personnel in the areas of advanced materials and nanotechnology, electronic, mechatronics, aeronautics, security and risk and information technologies, among other. The advisers in charge are professors and researchers, though eventually specialists from companies may also play such role. Students participate as collaborators and once graduated they do master studies and/or doctorate at the faculty, or other technological universities of the country or abroad.

Community servicies

The fundamental objective of this alternative is the immersion of the students in the environment, fostering solidarity and commitment with the community under the guidance of ethical norm and citizenship. By means of this insertion they are sensitized with the social necessities related with situations of poverty and less favored people exclusion. They are usually persuaded that the society in general and the university in particular can attenuate many of the difficult situations a large number of people is undergoing.

These services are related with campaigns of social support in the event of natural disasters, or droughts, among others. The FMEE periodically organized and event known as “Giving Smiles” that is traditionally supported by charity institutions and the participation of officials, administrative personnel and students.

These activities have been enriched and diversified from the model developed and logically through itself practice. From here the faculty departments involved are recording the evidence. However, it is considered that the brief characterization that makes from each one of them allows to be tested in other contexts since as is known the results depend on the circumstances which are implemented and the mechanisms established for this purpose.

Conclusions

The data gathered in this study show areas of opportunities and potentials for the satisfaction of the different agents taking part in the linking process. For these reason the authors reach at the conclusion that the interrelation among these agents needs to be perfected. One solution might be a comprehensive strategy allowing the increase of the efficiency of the linking patterns oriented towards the training of students, this focus on students’ education produces not only the traditional source of resources but the development of professional competencies, creating conditions for successful performance in the future labor context and its corresponding favorable impact on social development.

The results of the future engineer's formative process at the Faculty of Mechanics and Electric Engineering indicate that the models, ways and alternatives for the linking are more efficient when a synergy is achieved between all agents and implied factors. This synergy is based on conscious mobilization of enrolled agents to promote a truly objective and comprehensive education of engineers following a student-centered approach.

On the light of the objective of this chapter, the information gathered and findings have proved that the diversity of alternatives to link students to the environment contributes to their comprehensive education providing them a concrete and significant competence level. Naturally, each particular group of students and local industry will require a permanent systematization and renewal. The awareness of the alternatives potentials will in turn lead the search for new variants satisfying the steady technological and social development.

Similarly, the authors observed the necessity of strengthening the process of the student's education and in writing this chapter has coined it as *the formative approach* to the linking process. In a general sense, the following strengths and weaknesses are highlighted.

Strengths: There are favorable conditions for the interrelation of all the agents of the linking process and a positive valuation of the potential of the linking process for the student's formative process.

Weaknesses: The professor’s insufficient participation in the linking process and the agents’ poverty of arguments on the importance of the linking process for the engineering student's integral education.

Opportunities: The possibility of increasing the interrelation between the agents of the linking process, together with the capacity of the university to design the necessary strategies and to exert a leadership in the relations with companies and society in general.

Two different approaches to the linking process were clearly identified in this chapter. The possibility of following a *formative approach* contributing to would-be engineers’ education, without disregarding the university need to obtain resources proved that the design of a comprehensive strategy is viable. The linking process may and should go beyond obtaining resources.

References

Antúnez, M. (2011). Universidad y responsabilidad social. In *Reflexión Académica en Diseño & Comunicación* (pp. 206-210). Facultad de Diseño y comunicación. Universidad de Palermo.

ANUIES. (2000). *La Educación Superior en el siglo XXI. Líneas estratégicas de desarrollo. Una propuesta de la ANUIES.* Ciudad México: Asociación Nacional de Instituciones de Educación Superior.

Arocena, R. & Sutz, J. (2005). Latin American Universities: From an original revolution to an uncertain transition. *Higher education, 5*(1), 573-592.

Campos, G. & Sánchez, G. (2005). La vinculación universitaria: Ese oscuro objeto del deseo. *Revista Electrónica de Investigación Educativa, 7*(2), Available at http://redie.uabc.mx/vol7no2/contenido-campos.html.

Castillo, J. & Cols. (2013). *La vinculación y formación integral del estudiante de ingeniería.* Ciudad México: Pearson.

Castillo, J., Álvarez, N. & Cupich, J. (2014, June). Linking as a Potentiality for the Students Training at the Mexican University. *International Journal of Humanities and Social Science, 4*(8), 188-192.

Castillo, J., Treviño A. & Reynoso M. (2013). Gestión del proceso de vinculación en la Facultad de Ingeniería Mecánica y Eléctrica de la Universidad Autónoma de Nuevo León. *Educación y Futuro, 29*, 221-240.

García, C. (2014). Modelo de gestión con enfoque integral para el fortalecimiento de la dimensión formativa del proceso de seguimiento de egresados. Tesis doctoral. Universidad pedagógica Latinoamericana José de Martí. Monterrey. México.

Jiménez, JM., Díaz, JR, Díaz & Lloret, J. (2004). Desarrollo de un Plan Formativo Integral en Redes Corporativas para una Empresa, Internet Global Congress (IGC/INET2004), Barcelona (España), 10-14 de Mayo de 2004.

Lucena, J. (2006). Globalization and organizational change: engineers' experiences and their implications for engineering education. European Journal of Engineering Education 31, 321-338.

Luna-Arocas, R. & Camps, J. (2007),"A model of high performance work practices and turnover intentions", Personnel Review, Vol. 37 Iss 1 pp. 26 - 46 Permanent link to this document: http://dx.doi.org/10.1108/00483480810839950 Downloaded on: 03 November 2015, At: 11:32 (PT).

Martínez, F. (2000). *Nueve retos para la educación superior. Funciones, actores y estructuras*. Retrieved diciembre 16, 2013, from Asociación Nacional de Universidades e Instituciones de Educación Superior:
DOI: www.worldcat.org/.../nueve-retos-para-la-educacion-superior-funciones-

Sakthivel, P. (2007) "El compromiso de la alta dirección y la ingeniería en general la excelencia educativa", La Revista de la ACT, Vol. 19 Iss: 3, pp.259 – 273.

Shigwara, S. (2014, February). Effect of Implementing Transformational Leadership and Gobernorship in Assuming Societal Responsability by the Universities "The Middles East Univerty (MEU) is a Model. *International journal of Humanities y Social Sience, Vol.4, No., 4*(3), 127-150.

Zayas, R. (2011, enero-junio). Aprendizaje y vinculación entre universidades y sectores productivos. *Revista Mexicana de Agronegocios. Quinta Época, 28*(1), 515-528.