UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Computational assessing model based on performance and dynamic assignment of curriculum contents

Tesis doctoral

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To my family

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Resum

El procés de Bolònia anima la transició de l'educació superior des d'un model basat en l'adquisició del coneixement a un model que prima la comprensió de l'acompliment i des d'un model centrat en l'ensenyament a un model centrat en l'estudiant a través dels resultats de l'aprenentatge. Una avaluació centrada en l'alumne significa que l'estudiant analitza activament el seu propi aprenentatge amb criteris concrets sobre nivells de desenvolupament en un entorn on obté feedback de forma immediata, freqüent i formativa (Lancaster, Waugh and Wood, 2008).

Avaluar i qualificar són components molt rellevants del procés d'aprenentatge. Més encara, només un mètode d'avaluació sembla no ser suficient (Baartman, Bastiaens, Kirschner and Van der Vleuten, 2006). El fonament d'aquesta tesi consisteix en la introducció de conjunts molt diversos d'activitats en el procés d'avaluació amb l'objectiu d'enriquir-lo globalment i apropar-lo al procés d'aprenentatge. L'avaluació contínua es perfila com un dels mitjans més precisos d'executar el procés d'avaluació tenint en compte que les competències es poden adquirir mitjançant la realització d'activitats.

El procés d'avaluació s'implementa en una successió discreta de punts de mesura que denominem "moments d'avaluació" i que consisteixen en un conjunt d'activitats que són necessàries per al desenvolupament del procés. I basant-nos en l'existència d'una relació d'ordre parcial entre els diferents continguts d'un domini curricular, podem traçar un graf dirigit amb diverses cadenes de tòpics que representen, d'una forma natural, la progressió de l'alumne per assolir el perfil de competències objectiu.

L'avaluació per competències ens permet identificar llacunes en el desenvolupament de les competències així com les conductes que es requereixen per aconseguir les metes proposades (Levy-Leboyer, 1997). Proposem un nou procediment d'avaluació contínua introduint-hi un model actiu/retroactiu, basat en les cadenes de tòpics abans esmentades, que afavoreix la identificació d'aquelles competències que s'han assolit i també de les que no s'han assolit d'una manera adequada. Amb aquesta idea present, suggerim la introducció d'un impacte retroactiu sobre els coneixements base d'aquestes competències ja avaluats en la(les) corresponent(-s) cadena(-es) de tòpics dissenyades. I encara més, aquest impacte retroactiu podria ser més rellevant mitjançant la introducció

d'un amplificador d'impacte qualificador com un procediment d'avaluació contínua fonamentat en la major experiència i coneixement acumulat de l'alumne a mesura que avança el desenvolupament del curs.

Un aspecte important de l'avaluació per competències, introduït per Niss (2003), és la mesura del progrés en el nivell de desenvolupament de les competències durant el procés d'aprenentatge. En general, qualsevol assignatura es compon de diferents tòpics i cada tòpic es desenvolupa mitjançant l'execució, amb diferent rellevància, d'una sèrie d'activitats com classes magistrals, laboratoris, exercicis, etc ... D'aquesta manera, el nivell de desenvolupament de cada competència depèn del tipus d'activitats i de la recurrència amb què s'executen. Aquestes relacions entre activitats, tòpics i competències poden ser representades mitjançant matrius de tres dimensions a les que hem anomenat cuboides ATC.

Els cuboides ATC s'implementen mitjançant l'ús d'una avaluació binària que verifica en les activitats cadascuna de les competències bàsiques i les qualifica amb un indicador veritable/fals. Així, obtenim una estructura matricial del rendiment de l'alumne en el curs, la qual cosa ens permetrà dissenyar estratègies curriculars individualitzades adaptades a les necessitats particulars de cada estudiant amb l'objectiu que assoleixin el nivell requerit en cadascuna de les competències.

Desenvoluparem els esmentats cuboides ATC per a una mostra d'estudiants i els compararem amb els resultats obtinguts amb un mètode més tradicional utilitzat en el grau d'Enginyeria Aeroespacial a l'Escola Tècnica Superior d'Enginyeria del Disseny, ETSED, a la Universitat Politècnica de València.

Summary

The Bologna process encourages the transition of higher education from knowledge possession to understanding performances and from a teaching-centered to a student centered approach via learning outcomes. A student-centered evaluation means that students analyze actively their own learning with concrete criteria on development levels, in an environment where they obtain immediate, frequently and formative feedback (Lancaster, Waugh and Wood, 2008).

Assessing and grading are extremely important parts of the learning process. Furthermore, one single assessment method seems not to be sufficient (Baartman, Bastiaens, Kirschner and Van der Vleuten, 2006). The rationale of this dissertation consists in introducing the execution of disparate sets of activities into the assessment process in order to enrich the whole procedure keeping it close to the learning process. Continuous assessment seems to be the most accurate mean of executing the assessment process taking into account that competencies are achieved by executing activities.

The evaluation process is implemented throughout a discreet number of measurement points called "moments of evaluation" which consist in a set of activities necessary for the development of the process. And based on the existing partial order relationship among specific curricular domains we could draw a directed graph with several chains of topics representing a natural way of progress in order to reach the profile competences.

The competency assessment allows us to identify gaps in the performance of the competencies, as well as the behaviors that are required in order to achieve the proposed goals (Levy-Leboyer, 1997). We propose a new procedure in continuous assessment by introducing an active/retroactive model, based on the aforementioned chain(s) of topics, which aims to identify those competences that have and those that have not been adequately achieved. With this in mind we suggest introducing a retroactive impact on the outcome assessment of the concerned competencies evaluated in the corresponding chain(s) of topics. These retroactive impacts might be amplified by the introduction of a grade impact amplifier as continuous assessment

procedure based on the greater experience and knowledge of the students as the course advances.

An important aspect of the competency assessment defined by Niss (2003) is to measure the progress on the achievement level of the competencies throughout the process of learning. In general, any subject is composed by different topics and each topic is developed through the execution, with different relevance, of a number of activities such as lectures, laboratories, exercises, etc. In this way the level of achievement of each competence depends on the type of activities and the recurrence of their executions. Relationships between activities, topics and competences can be distributed in a 3D matrix array which we will call ATC cuboid.

ATC cuboid uses a binary assessment as a check of an activity in each of the core competencies. In this way, we have a matrix structure of the performance of the student over a course, which is the basis to design individualized curricular strategies with the goal of achieving the required level of development of each competence.

We will develop the aforementioned ATC cuboids on a sample of students and a comparison between this method and a more traditional method used with Aerospace Engineering students in the Design Engineering School ETSID at Universitat Politècnica de València (Valencia, Spain).

Resumen

El proceso de Bolonia anima la transición de la educación superior desde un modelo basado en la adquisición del conocimiento a un modelo que prima la comprensión del desempeño y desde un modelo centrado en la enseñanza a un modelo centrado en el estudiante a través de los resultados del aprendizaje. Una evaluación centrada en el alumnado significa que el estudiante analiza activamente su propio aprendizaje con criterios concretos sobre niveles de desarrollo en un entorno donde obtiene feedback de forma inmediata, frecuente y formativa (Lancaster, Waugh and Wood, 2008).

Evaluar y calificar son componentes muy relevantes del proceso de aprendizaje. Más aún, sólo un método de evaluación parece no ser suficiente (Baartman, Bastiaens, Kirschner and Van der Vleuten, 2006). El fundamento de esta tesis consiste en la introducción de conjuntos muy diversos de actividades en el proceso de evaluación con el objetivo de enriquecerlo globalmente y acercarlo al proceso de aprendizaje. La evaluación continua se perfila como uno de los medios más precisos de ejecutar el proceso de evaluación teniendo en cuenta que las competencias pueden adquirirse mediante la realización de actividades.

El proceso de evaluación se implementa en una sucesión discreta de puntos de medida que denominamos "momentos de evaluación" y que consisten en un conjunto de actividades que son necesarias para el desarrollo del proceso. Y basándonos en la existencia de una relación de orden parcial entre los distintos contenidos de un dominio curricular, podemos trazar un grafo dirigido con varias cadenas de tópicos que representan, de una forma natural, la progresión del alumnado para alcanzar el perfil de competencias objetivo.

La evaluación por competencias nos permite identificar lagunas en el desarrollo de las competencias así como las conductas que se requieren para alcanzar las metas propuestas (Levy-Leboyer, 1997). Proponemos un nuevo procedimiento de evaluación continua introduciendo un modelo activo/retroactivo, basado en las cadenas de tópicos antes citadas, que favorece la identificación de aquellas competencias que se han y que no se han alcanzado de una forma adecuada. Con esta idea presente, sugerimos la introducción de un impacto retroactivo sobre los conocimientos base de estas

competencias ya evaluados en la(s) correspondiente(s) cadena(s) de tópicos diseñadas. Es más, este impacto retroactivo podría ser más relevante mediante la introducción de un amplificador de impacto calificador como un procedimiento de evaluación continua fundamentado en la mayor experiencia y conocimiento acumulado del alumno conforme avanza el desarrollo del curso.

Un aspecto importante de la evaluación por competencias, introducido por Niss (2003), es la medida del progreso en el nivel de desarrollo de las competencias durante el proceso de aprendizaje. En general, cualquier asignatura se compone de distintos tópicos y cada tópico se desarrolla mediante la ejecución, con distinta relevancia, de una serie de actividades como clases magistrales, laboratorios, ejercicios, etc… De esta forma, el nivel de desarrollo de cada competencia depende del tipo de actividades y de la recurrencia con que se ejecutan. Estas relaciones entre actividades, tópicos y competencias pueden ser representadas mediante matrices de tres dimensiones a las que hemos llamado cuboides ATC.

Los cuboides ATC se implementan mediante el uso de una evaluación binaria que verifica en las actividades cada una de las competencias básicas y las califica con un indicador verdadero/falso. Así, obtenemos una estructura matricial del rendimiento del alumnado en el curso, lo que nos permitirá diseñar estrategias curriculares individualizadas adaptadas a las necesidades particulares de cada estudiante con el objetivo de que alcancen el nivel requerido en cada una de las competencias.

Desarrollaremos los mencionados cuboides ATC para una muestra de estudiantes y los compararemos con los resultados obtenidos con un método más tradicional utilizado en el grado de Ingeniería Aeroespacial en la Escuela Técnica Superior de Ingeniería del Diseño, ETSID, en la Universitat Politècnica de València.

Not everything that can be counted counts,
and not everything that counts can be counted.
Albert Einstein

1 Introduction

1.1 Motivation

Throughout my professional career I have had the opportunity of teaching in multiple occasions and in a wide variety of scenarios.

In the 80's I was a Math teacher for 7 years and the Head of Studies for over 6 years at a Secondary State vocational training school. Back then, vocational training's approach was more practical, and for that, the main subjects were used as a technical base in order to develop professional skills.

Concurrently, I had the chance of teaching at a private agrarian school whose educational system was completely different and based on alternation/rotation. Students alternated 15-day periods of boarding and 15-day periods working on agricultural holdings, whether they were theirs or not, and where they made use of the techniques they had acquired during the boarding period.

Surely both educational systems differed. The former's point was to learn basic concepts and to develop professional skills during practices. The latter's objective was to develop competences by alternation of studying and working.

The former's assessment system was comparable to the ones we find nowadays in most educational institutions. Assessment basically is the result of written test's scores and in some cases there is an assessment about the practice sessions, where the final score is deduced by the weighted average. In the latter's case, while being a similar method, there was a prevailing component regarding assessment in terms of competences and continuous assessment since after each stay at the agricultural holdings students were tested on the outcomes obtained from the techniques or procedures applied.

In the last 15 years I have occupied the position of director of business intelligence projects at a bank with thousands of employees. Among other things, we trained business analysts in managing and elaborating information. Here the assessment system is clearly a competence assessing one. It was tested whether the person was able to carry on the work as efficiently as it was supposed to, otherwise, the person might be placed somewhere else. This is how competences affect real professional life and it is key to be prepared for it.

As a consequence to all these years' expertise I have also come to the conclusion that developing competences is highly important. In order to guarantee this development, it is needed an assessment system which grading about competences can be reliable.

In this respect, continuous assessment is of major importance not as an average of tests but as a weighted average that encompasses all of the student's work and effort along his academic life.

We have analyzed 38 mathematics learning guides of Aerospace Engineering degrees from 10 Spanish universities websites in order to study how continuous assessment is approached. The following table shows the results of this study.

Qualitative aspects	**#Items**	**% over sample**
Documents analyzed	38	100.00
Competences are detailed	33	86.84
Outcomes are detailed	38	100.00
Relate outcomes and competencies	28	73.68
Continuous asessment is referenced	24	63.15
Specific section for continuous assessment	33	86.84
Relationship between competences and activities	10	26.31
Other activities than witten exams are taking into account	15	39.47
Other activities/Continuous assessment not referenced	7 over 33	21.21
Other activities/Continuous assessment referenced	8 over 33	24.24

*References [166] to [176]

The majority of learning guides from the analyzed subjects relate to general and specific competences as well as learning outcomes. They all describe different kinds of activities that are taken into account for the final grade to a greater or lesser extent. A smaller percentage relates activities to the development of competences, and only 10 of them do it systematically and in detail.

Some of them refer to continuous assessment explicitly and 33 of them allot a visible section to discuss how it is going to be executed. Generally, they use a weighted average to two or three written tests with a small contribution from other activities such as laboratory practices. The other ones do specify in more detail how to implement a quantification of other activities with a higher weight in the assessment system. Two of them detail with a great assortment of activities such as work groups, presentations and do on.

Nevertheless, there are plans that consider the implementation of different activities not relating to a continuous assessment method at all (7 out of 33). Only in two of them there are a reference regarding the possibility of retrieving past contents through successful results from later tests, which presupposes the existence of previous knowledge and it is an implementation of the retroactivity concept we are going to explain in this dissertation.

At the Universitat Politècnica de València, the Superior Technical School of Industrial Design, ETSID, offers the degree of Aerospace Engineering. The mathematics programme has put effort in the implantation of continuous assessment developing procedures for assessing which consider the expertise acquired by the student.

After many conversations with Professor Luis Manuel Sánchez Ruiz, director of this dissertation, in which we commented on experiences concerning assessment, competences and the future about education in coming generations, he coaxed me into reading about research on this topic so that I became increasingly interested in working on this topic and writing about a computation procedure for continuous assessing as a formalization of the methods applied.

1.2 Objectives and methodology

The main objective of this dissertation is the specification of a calculation procedure to obtain qualifications in a continuous assessment system. Assessment is intended to 'measure' what a student has learned and the competences developed during the time the course lasts. The learning outcomes can be estimated by demonstrating the ability to develop studied procedures and/or techniques that have been practiced throughout the course. Normally, through carrying out tests, oral or written, in a controlled environment to ensure the authorship of these tests. Measuring the development of competences is much more complex, as the students should be in an appropriate professional context to observe their behavior and professional execution, which is not always possible in all subjects, though students have time to go on placements in companies where this facet can be observed.

A written test that demonstrates the developed skills has uncontrollable negative factors that affect the reliability: stress caused by the need to pass, fatigue by overexertion, etc.

The concept of continuous assessment is a utopia in a way, which we would like to approximate the mathematical concept of continuity. Time is a continuous variable, but the actions we perform for a particular objective are discrete actions. The learning process is not so far from this utopia since we learn not only in class but also talking to classmates, teachers or friends, we learn walking around and observing, among other things. We are in a setting of continuous inputs of information, and whilst not every input is a mathematical one, the mathematics we study are used daily in many different ways. Decisions are made based on an estimated probability, we surf within social networks which are immense relationships graphs

We wonder, why do we not consider any thing the student does regarding the subject when assessing? It will not be “continuous” mathematically speaking but it will surely be more “continuous”, our objective being for it to be as continuous as possible, ACAP.

It is helpful to remember that the word “assessment” comes from the Latin term *ad sedere*, meaning “to sit down beside.” When we assess, it should be as if we are pulling up a chair next to individual students, getting down on their level, and putting ourselves in their corner to give them information that will help them succeed (Talbert, 2014).

And, does everything affect the learning process and the development of competences? By all means. For instance, at lectures, students learn nuances of concepts that would not be perceived if not by attending, supposing they pay attention. They develop the communication competence by seeing their teacher do it and argue about subject topics with classmates.

What if students solve problems and questions outside the classroom? They also learn by using the studied concepts and try to put them into practice. And, what about if help is offered? They learn through reliable people, too, since they enlighten them on reasoning students could not think of at first.

ACAP's target is not only sustained by the implementation of how many measuring or assessment points are possible. It aims, in the performance of these actions, to take into account the necessary background in order to finalize and prompt past performances' re-evaluations. This leads to the concept of retroactivity which is basically the manifestation of the continuous assessment character that attempts to make contributions to the assessment measure in parallel with the student's effort and achievements.

A second objective is to implement an assessment procedure which allows to *appreciate* the development of the mathematics competences embedded in the performance of the studying and learning processes by means of a rubric system that qualifies certain aspects such as the capability to communicate or mathematical reasoning and also quantifies the capability to resolve problems. Not to forget that the procedure requires a final score that is compatible with the traditional assessment methods.

Its purpose is to obtain a greater granularity of information of the one expressed as a final grade and also provide a vision of the student's performance in the learning process from the competences point of view.

A third objective is to draw up a path towards individualization of the learning programs. This idea, which is key within a children educational environment given that they promote integration in education and curricular adaptation, is not so clear in higher education. Be that as it may, the implementation of technologic systems that contribute to the study with assessment capacities might help design and complement the student's learning program adapted to particular needs.

This dissertation is not set to establish learning methods or new assessment techniques. It is based on the use of existing assessment tools commonly used in these educational levels, and the purpose is to formalize to what extent the use of them can be quantified in the assessment, trying at all times to follow a time sequence and promoting a contributive measurement of the effort considered as an expression of the continuous assessment.

The methodology followed is based on the observation of the use of the assessment tools, both formative and summative. The correlation of these instruments with the development of the mathematical competences is what will enable us to establish a quantification of the formative actions and their performance by the students. With this quantification and an additive method of contributions based on a streaming of performances with continuous feedback, both in current and past performances, we try to settle a final grade related to the student's performance and an estimation of the evolution in the achievement of basic competences.

In contrast with the previous method, a sample of students with different levels of performance in a subject has been selected and the available material re-evaluated (mainly written tests and registered laboratory practices) so as to compare the learning outcomes obtained at school and end up concluding that this method does not divert much. Anyway, in the studied subject from ETSID there exists a great experience in the use of continuous assessment; consequently the result was to be expected. This enables us implementing in the future the concepts covered in this dissertation on the assessment system. As we shall see in due time, adopting a system of these characteristics requires technological systems to help assessment and self-learning since, otherwise, its use requires an effort that cannot be borne by the people in charge of the assessment.

1.3 Contents

This work is composed of thematic chapters which go through the use of the instruments for assessing and bring in concepts about computer procedures of an assessment method based on efficiency and dynamic assignment of the contents.

Chapter 2, the assessment process, is a review of the background about the importance of assessment. It covers the different types of assessment according to their function, the moment of application, the person that assesses or the person that is assessed. It is referred to as the nature of assessment and is looked at from an historical perspective.

Chapter 3, activities and competences, defines basic mathematical competences introduced by Niss in the KOM project and the interpretations of SEFI, Mathematical Working Group and OECD Pisa. There are classified different types of training activities which are carried out with students or are run by them to then study how activities and basic competences are related.

Chapter 4, a procedure to compute continuous assessment, introduces the concept of continuous assessment, which stands up for this dissertation. Also, the concept of active and retroactive assessment is one of the pillars on which the procedure is based.

Chapter 5, ATC cuboids in assessment of mathematical activities, brings in the concept of binary assessment as a system of rubrics true/false about the relation of competences with the activities. A data structure, ATC cuboids, is built in order to allow registering and quantifying the binary assessments of each student and form the streaming system which comes along with the assessment of the student. The concept of master ATC as a metric structure that makes the quantification possible is also settled.

Chapter 6 examines the assessment of a sample of students from the ATC perspective. In this chapter it is detailed step by step how each of the elements of the ATC structures compute through the creation of the backlog of activities and the use of metric structures. Given that this students' material from the selected sample is re-evaluated, we have described in detail this re-evaluation for one of them emphasizing some of the aspects of the binary assessment and the criteria followed. It is detailed the way in which a component of retroactivity based on rules in an additive and novel way. It also explains a new concept, GIA, which amplifies the impact of the activities of the student on the assessment system based on the acquired experience as the course progresses. The sample is compared with the results obtained by these students in the ETSID.

Chapter 7 explains in a very general way the foundation for constructing a model of information that can sustain the assessment method by using computerized systems which assist the assessment to allow to do the feasible method. In this chapter there are included the basis for formulating algorithms based on banks of activities and estimation methods which enable the implementation of individualization of the résumés adapted to the particular needs of each student. As mentioned before, it is a general chapter that is not intended to be a formal design. Formalization requires a far more extensive and expensive technological project from which we have no more than a few basic concepts.

Finally, Chapter 8 consists of a final discussion of the presented method and its results. It strives to answer the issues raised throughout the dissertation and visualizes the future advantages that kind of system might bring in assessment. It also tries to devise future work paths along this line, although there is a wide variety of studies aiming at this type of work methods based on predictive modelling, banks of activities and traditional business intelligence techniques implemented in educative intelligence also known as learning intelligence.

After the references, it is shown the results of the ATC assessment of all the students of the sample studied in chapter 6.

1.4 Background

This dissertation fits within some Innovation and Teaching Projects, “Ayuda a Proyectos de Innovación Docente”, namely:

- PID-DMA-2013, Department of Applied Mathematics, UPV 2013; PIME B-11, B-12, Vice-rectorate for Studies and Convergence with Europe (VECE), UPV 2012.
- PID-DMA-2013, of Department of Applied Mathematics of the Universitat Politècnica de València UPV 2013, Project for Innovation and Educational Improvement; PIME B12/12, Vice-rectorate for Studies and European Convergence (VECE), UPV 2012; and PIME/2013/A/025/B, Vice-rectorate for Studies, Quality and Accreditation (VECA), UPV 2013.

- PID-DMA-2014, of Department of Applied Mathematics of Technical University of Valencia UPV 2014; Project for Innovation and Educational Improvement PIME B024, Vice-rectorate for Studies, Quality and Accreditation (VECA), UPV 2014.

2 The assessment process

2.1 Introduction

The main objective of this dissertation is the study of a computational model to build the continuous assessment as a tool to estimate and control the development of the students' skills which allows the students and educators a better planning and a major probability of success in their targets achievement.

As skills have just been mentioned and this dissertation is mainly concerned with the assessment competences, it may be convenient to recall the related concepts of knowledge, skills and competences. We reproduce a synthesis of the discussion about these terms found in Hoffmann (2011a).

The simplest cycle of learning is learning by heart, initiated by directing attention to pieces of information called facts which when hold sufficiently long in the working memory turn the knowledge into factual knowledge. After that, making context associations we obtain conceptual knowledge, or episodic knowledge when arranging in sequence facts in their contexts. The entirety of factual, conceptual, and episodic knowledge is categorized simply as (passive) knowledge.

The experience stored as episodic knowledge motivates thus for training of a sequence of actions which implies gaining knowledge on procedures to be performed, or shortly procedural knowledge. If learners have knowledge about the rules behind the procedures, then they obtain the so called canonical knowledge. Then, skills are the *abilities achieved by actions motivated through episodic knowledge, trained as procedural and canonical knowledge.*

The ability to find further rules actively and autonomously based on formerly acquired canonical knowledge generates analytical knowledge. Using their analytical knowledge, learners are able to plan what to do in particular situations, and without having trained these actions. Then, the learners have acquired competences.

The different types of evaluation, in general, are a control instrument embedded in the learning process. Therefore the evaluation will become part of this process and should also become part of any estimation algorithm that is intended to measure the learning process.

In this chapter we include a brief review of the importance of the process of evaluation and a classification of the different types of evaluation. Nevertheless, the primary target of this work is to model an estimative process based on the continuous assessment for competences through the activities execution.

The evaluation is a process through which it is observed, gathered and analyzed relevant information from the students' learning process. The main purpose is to reflect, express value judgments and make pertinent and opportune decisions to improve the process of education - learning (Díaz-Barriga 2006).

Teachers make a wide variety of decisions. Assessment is the process by which teachers gather and organize information to help them make the different decisions (Kapambwe, 2009). It should be a holistic process through the use of multiple assessment procedures (Atkin and Black, 1996). In this sense it is important to determine the extent to which a set of assessment tasks provides a relevant and representative sample of the outcomes achieved (Linn and Gronlund, 1995).

Evaluation is also a systematic process of data collection and analysis with the purpose of determining whether objectives have been or are being achieved. The resulting information is placed at the service of the decision-making (Boulmetis 2005).

The Laboratory Network Program (1993) emphasizes the need for the process to be reliable, valid and fair:

- Reliability means that evaluations must be "an indication of the consistency of scores across evaluators or over time." An assessment is considered reliable when the same results occur regardless of when the assessment occurs or who does the scoring. There should be compelling evidence to show that results are consistent across raters and across scoring occasions.
- Validity means that evaluations must be "an indication of how well an assessment actually measures what it is supposed to measure." The reference identifies three aspects of an assessment that must be evaluated for validity: tasks, extraneous interference, and consequences.
- Fairness means that an assessment should "enable students of both genders and all backgrounds to do equally well. All students should have equal opportunity to demonstrate the skills and knowledge being assessed." The fairness of the assessment is jeopardized if bias exists either in the task or in the rater.

The evaluations are implemented through different instruments and thus it is not estrange to make reference to them in order to be able to clearly define the concept or modality of evaluation. In this dissertation we always refer to the use of any instrument, either with evaluative sense or not, as for the execution of an activity.

There exists a wide diversity of types of evaluation paying attention to different criteria and contents. Many of the concepts overlap between themselves since it is a complex process that attends on very diverse psychological, social and behavior aspects of the persons. We do a review of the most important ones.

2.2 Evaluation according to its function

As regards the function of the evaluation, one of the most basic classifications distinguishes between diagnostics, formative and summative.

2.2.1 Diagnostic Assessment

This evaluation attempts to set initial conditions of learning opportunities and identify the needs, strengths, and limitations of a collective of students that is beginning a training cycle, which makes it coincide with the start of the cycle. Its fundamental mission is to classify the collective and adapt the learning path. It can be used in continuous assessment models in the beginning of every thematic block generating a continuous diagnosis that enables to level punctual and dispersed shortcomings.

As stated in the Decree 121/2013, of September 13, the Consell of the Regional Government of Valencia, which regulates the diagnostic evaluations in the educational centers supported by public funds in the Comunitat Valenciana, in the second article, paragraph (1): "... the diagnostic evaluations will have a formative character and guiding for the centers, and informative for the families and the whole of the educational community. In addition, they will aim to check the degree of development of the core competencies achieved by the students and will take into account contextual factors of cultural character.

Their main characteristics relate to its informative nature for the centers and the Administration, and for guiding the implementation of improvement processes. It does not have academic effects; neither establishes qualifications nor values given contents.

2.2.2 Formative assessment

This evaluation is set as a feedback loop between student and teacher while the learning process advances in order to point out the learning problems and is able to plan corrective actions in time. Therefore, its main function is monitoring and the increasing of the quality of teaching.

The formative evaluation consists in evaluating the progress and the knowledge of the students in a frequent and interactive way. Thus the teachers can fit the programs to satisfy better its educational needs (OECD 2005). *Op. cit.* analyzes in depth the formative evaluation and its principles, as well as its benefits and problems.

Formative assessment, therefore, is essentially feedback (Ramaprasad, 1983) both to the teachers and to the student about present understanding and skill development in order to determine the way forward (Harlen and James, 1997).

Formative assessment is defined as assessment carried out during the instructional process for the purpose of improving teaching or learning. What makes formative assessment formative is that it is immediately used to make adjustments so as to create new learning (Shepard, 2008).

Some of the techniques used in formative assessment consist in making a series of questions to students or groups of students within lectures to determine if the treated concepts are being developed properly. The feedback obtained from the students' work its in multiple forms: homework, essays, working groups, laboratory practices, test at the end of the class, etc. All of them let us verify the proper understanding of the concepts and development of skills and also allow us to change the planning for next classes according to the results.

Black and Wiliam (1998) define assessment broadly to include all activities that teachers and students undertake to get information that can be used diagnostically to alter teaching and learning. Under this definition, assessment encompasses teacher observation, classroom discussion, and analysis of student work, including homework and tests. Assessment becomes formative when the information is used so that teaching and learning is adapted to meet student needs.

2.2.3 Summative assessment

Summative assessment tries to certify the degree of achievement of the course objectives, either in an intermediate point or at the end of an educational cycle. Its main purpose is to assign a grade to each student that reflects the proportion of goals achieved in a period.

The summative evaluation can be used sometimes like diagnostic when it is implemented in intermediate periods. Nevertheless, it differs from formative evaluation since its target is to generate a final grade.

Some of the instruments used in the summative evaluation may include an evaluation by rubrics where previously the evaluation criteria are given to the students (rubrics or descriptions of the expectations on the work to be done by means of diverse execution grades).

The terms formative and summative were already introduced by Scriven (1967) with the famous example of "when a cook tries the soup it is formative whereas when it is the customer who does it is summative".

A criterion that distinguishes between formative and summative evaluations is that the former accredits achievements when certain conditions are met. These might require an evaluation instrument aligned with the contents to be learned that should discover specific problems of learning so that decisions based on them could be taken and, accordingly, to plan corrective measurements on due time. Some of these conditions are likely not to be met by evaluations whose primary objective is summative.

The diagnostic, formative and summative assessment constitutes the main classification of the types of assessment. Other classifications pay attention to the objectives or at the moment of its application and so on. They may be assimilated to these three types of evaluation.

2.3 Evaluation according to its timing

Concerning the moment in which the evaluation is applied, there is straightforward classification:

2.3.1 Initial assessment

The purpose of the initial assessment is to establish a realistic baseline at the beginning of a training cycle. Although it could be seen as a bureaucratic tool if the curriculum of the training cycle is well defined, some authors like Muriel (2002) consider the initial assessment needs to be done. It should be of benefit to learners and help them feel positive about themselves and their potential to learn.

The results of the initial evaluation provide us the first judgments on the student, focus and level of learning as well as skills and needs that must be developed.

According to Muriel, assessment is both backward and forward-looking. In other words it makes judgments about previous learning and achievements whilst at the same time attempting to give indications or measures, of the learner’s capacity to progress along one of a number of pathways. The outcomes of the process shape and support the learning process that can best secure achievement and progression for the individual learner.

This form of evaluation must be centered on learning. Feedback is important and should assist in designing the learning plan against an initial closed plan. It does generate important information about the strengths and weaknesses of the students and allows educators to set short-term goals and new goals. It must be based on previously acquired knowledge, highlight the interests, skills, and the potential for learning. In this sense is the same concept as the diagnostic evaluation aforementioned.

2.3.2 Partial assessment

Partial evaluation seeks to establish intermediate points to check the level of development of learning throughout the learning cycle. The instruments used are those of any type of evaluation. The term in reality makes reference to the time of application and not to its content. It has been used, in general, as a synonym for continuous assessment in the sense that it provides intermediate points of measurement and these points can serve to set up a system of estimate final grades.

It is an instrument of feedback for both trainers and students in the sense of establishing measurement points in time, while these measures are strongly influenced by the activities that include the evaluation as well as the extension of the content to cover. If the obtained results re-feed for rethinking over the procedures of learning, this evaluation will have many similarities with the formative evaluation.

2.3.3 Final assessment

An assessment is said to be final when performed at the end of a complete training cycle. Its purpose is to provide a final grade or contribute to it depending on the form in which it is implemented. Sometimes used as a means of second chance although it is also useful as a shifted evaluation, with respect to the partial evaluations, to measure the persistence of acquired knowledge. It can be assimilated to a summative evaluation.

2.4 Evaluation according to its performer

Other forms of assessment are based on the person that triggers the process of assessment considering internally to the teacher or the students themselves, as well as those raised by external agents to the educational environment.

2.4.1 Self-assessment

Self-assessment has been defined as “the involvement of students in identifying standards and/or criteria to apply to their work and making judgments about the extent to which they have met these criteria and standards” (Boud, 1991). According to Boud there are two parts in this process: the development of criteria, and the application to a particular task.

Assessment decisions can be made by students on their own essays, reports, presentations, projects, dissertations and so on, but it is believed to be more valuable when students assess work that is personal in nature, like a learner log, portfolio etc… (Race, 2001).

Here a key role is assigned to the student because he or she is the one who carries out the process of evaluation once the instructor have determined which learning is to be self-assess and how it should be developed.

2.4.2 Peer-assessment

Peer assessment may be defined as the assessment of the work of others of equal status and power (Wilson, 2002). In the context of student learning, peer assessment is used to estimate the quality of other students' work, and to give and receive feedback. With appropriate training and close moderation, it gives a chance to students to play a role in summative assessment, but generally peer assessment works best in formative assessment where students give each other feedback on each other's work.

Self-assessment and peer-assessment are usually reliable if specified criteria are met, the students have had the opportunity to put into practice the techniques of evaluation, classification instruments are simple and a second indicator is used to moderate the evaluation. In essence, if a student understands the needs of training and the process is managed properly, then it is surely a positive and constructive process for all those involved.

This type of assessment encourages them to develop teamwork skills and promotes active rather than passive learning. It also develops verbal communication skills, negotiation skills, and diplomacy (Riley, 1995).

2.4.3 External evaluation

The external evaluation is presented as a comparative mechanism with the aim of normalizing the educational programs, as well as to generate feedback to practitioners of education within a context of comparison and standardized procedures.

Program for International Student Assessment (OECD 2009) is one of the most recognized frameworks to implement external benchmarking in educational systems. It represents a commitment by Governments to monitor the results of educational systems through the measurement of achievements of students within a common framework internationally agreed. Its objective is to provide a new basis for policy dialogue and the collaboration in the definition and implementation of educational objectives (OECD, 2013). It is the most comprehensive and rigorous international programme to measure the performance of students and the study of institutional factors that can help explain differences in performance. Mechanisms for quality assurance in translation, testing and data collection are very rigorous, so the PISA results have a high degree of validity and reliability.

2.5 Curricular assessment

The principles of this modality consist in setting objectives for a unit or educational cycle, to select these objectives contents and the same learning experiences consistently, to integrate these contents and experiences into the learning process, and finally, to evaluate (Wheeler 1985).

We can frame the external evaluation within a model of curriculum development. Some authors like Tyler (1967) reported that the evaluation should focus on the final results to verify that the objectives initially set have been met. Aubrey (1982) also states that there must be a process of initial evaluation and at intermediate points.

Its main characteristics include the integration of assessment with the process of the curricular development. It promotes the curricular enrichment as well as the formative evaluation, it generates feedback to educators and students, helping to define criteria for the activities portfolio design and promotes the participation of all actors (Stuffelbeam and Swchinkfield, 1989). These characteristics are common to most of the types of evaluation. Other authors consider the evaluation as an integral part of the curricular development (Zabalza, 1977).

2.6 Evaluation according to its nature

2.6.1 Criteria and normative assessment

These evaluation forms tend to be stricter as soon as they consider fundamentally quantitative aspects of the process of evaluation.

The normative evaluation examines the position of each student regarding to the others on the basis of some indicators to measure and establish an order arrangement of them. Popham (1983) defines it as a test based on rules of normality destined to determine the position of a student regarding a group of other students that has taken the same test. Nevertheless, it is not an evaluation adapted to measure the individual skills.

On the other hand, the criteria evaluation aims to measure the achievement of objectives by each student without comparing it with the group (Gomez Arbeo, 1977). Therefore, it is a form of evaluation focused on learning, with preset goals and measurement of elements to determine if each student reached individually the curricular objectives.

2.6.2 Qualitative and quantitative assessment.

The qualitative assessment is an evaluation based on concepts where the process of obtaining information is based on judgments of value with qualitative categories or classification rather than a quantification of performance. In a qualitative assessment, evaluation criteria must be conceptual and descriptive guiding the students about their mistakes, successes, what has failed, weaknesses and strengths, etc. Some of the methods of assessment approaching this model use evaluation by rubrics.

The qualitative assessment aims to promote in students their autonomy and ability to participate responsibly in their own process of personal and social development. Evaluation does not emphasize on the achievement of final behaviors in terms of knowledge, but it promotes the process of continuous improvement of the student as a person free, dignified and participatory person (Alfaro, 2000).

The use of techniques of qualitative evaluation has drawn criticism regarding its lack of objectivity, no reproducibility of results and limited validity against the quantitative methods that are generally well accepted. Among the various currents of opinion, constructivism is the paradigm that has had a greater influence on qualitative methods.

To constructivism there is not an objective reality but this is socially constructed and, therefore, different mental constructions of the same reality can co-exist even if some of them come into conflict. In this way, and through the study, perceptions of reality can be modified (Mertens, 2005).

The qualitative evaluation implies the active participation of the student. The collection of information is more verbal than quantitative, more emphasis is placed on the process than in the result.

In contrast, the quantitative evaluation determines the grade of achievements of the programmed targets. It is based on quantifications and is the way in which the validity of the educational process is determined.

2.6.3 Continuous assessment

According to Ezewu and Okoye (2002), continuous assessment should be systematic, accumulative and guidance oriented. Systematic in the sense that is planned and is given at predetermined time intervals during the academic year. Accumulative characteristics of continuous assessment means that all information gathered on the individual has to be pooled together before a decision can be taken. And oriented guidance means that the information so collected is to be used for educational, vocational and personal decision-making for the student. Conceptually, op. cit, continuous assessment provides feedback to learners and teachers and provides feedback information which is used for purposes of improving on the student's performance.

Other authors define continuous assessment as a mechanism whereby the final grading of learners in the cognitive and affective domains of learning systematically takes account of all their performances during a given period of schooling (Falayajo Wole 2006), or an assessment approach which should depict the full range of sources and methods that teachers use to gather, interpret and synthesize information about learners (Airasian, P. W. 1991).

2.7 The evaluation in a historical perspective.

The first generation of evaluation methods focuses on the development of evaluative tools and media where the concepts "evaluation" and "measurement" are synonymous. The student is a passive player. It is methodologically based on the unilateral character of the evaluator that judges and decides on the level of learning. The evaluation is essentially quantitative. Here the sense of evaluation is the process of delineating, obtain and provide valid information for decision-making (Chadwick and Rivera, 1991). This is done at the end of the process; for that reason its mission is mainly administrative to certify the learning process and enabling the student's promotion.

The second generation from the 30s till the end of the 60s, incorporated the descriptive techniques of the strengths and weaknesses in relation to the achievement of objectives. Attention focuses on the student curriculum pairing. At this stage the assessment is formative and summative and is based on previously planned objectives. The role of the evaluation is the process that determines to what extent the proposed educational objectives have been achieved (Morales, 2001). In essence it is an achievement-oriented evaluation.

The third generation is based on the emission of judgments on the performance of the student. The evaluation focuses on the analysis of the learning process in a systematic and well defined way. Its main features are its functionalist and experimental character without valuable or ethical considerations. (Alfaro, 2000).

The fourth generation appears in the 90s and it is based on the constructivism and not conventional methodologies. Some authors refer to it as the generation of bargaining (Guba and Lyncoln, 1989). The knowledge is created from experiences, the student takes part actively with autonomy and in group meetings. The evaluation is essentially qualitative. The figure of the formative evaluation is incorporated. It is encouraged the self-assessment and peer-assessment. And it plays an important role to ensure the fair exercise of evaluation in which each actor can assert its own word and his own argument (Alvarez Mendez, 2005).

Nowadays, the fifth generation focuses on the quality in education. The students must recognize their strengths and their own weaknesses. Looking for the integration and participation of all actors, evaluation has a character of lifelong learning. The evaluation is done based on the implementation of very different activities such as testing, quizzes, working groups, etc. The assessment becomes a continuous process that generates feedback for students and teachers engaged in a process of continuous improvement.

Very recent contributions point out some doubts on the reliability of evaluations of acquired knowledge, skills and competences at early stages. In this line, Hoffmann (2011a) suggest to plan a combined strategy that motivates learners to use their recently acquired knowledge, skills and competences continuously and over a longer period of time and to assess these at least once two months after the end of the course.

3 Activities and competencies

3.1 Introduction

The conductive thread of this thesis is the establishment of a computational algorithm that serves as support to the continuous assessment process pursuing several targets simultaneously:

- To cover as many items as possible to be evaluated in the process.
- To measure the evolution of the learning process by learners and teachers and to estimate the degree of achievement of the final objectives
- To serve as a self-diagnostic tool to situate the student's position within the learning process.
- To facilitate identifying the knowledge gaps with the aim of fitting and adequate workload to correct them.

From our point of view the process of continuous assessment is to be based on the measurement of the execution of activities encompassing most aspects of the learning process for which we use a model of assessment by competencies.

Since the basic idea refers to the execution of formative activities and their evaluation, two key questions arise:

Q1: What type of activities should be introduced in the evaluation process?

Q2: How does the execution of different types of activities contribute to the development of mathematical competences?

We initiate this chapter by reviewing some opinions about the assessment for competencies. We will follow the conceptual model developed by Niss (2003) and by the work of the SEFI Mathematics Working Group 2013. We include a list of the types of formative activities and its relationship with the development of competencies.

3.2 The concept of competence

One of the most debated concepts over the ten years of implementation of the European Higher Education Area (EHEA) is the concept of competence. And insight of the competences vs competencies terminology was developed in Section II and III of Edwards, Sánchez Ruiz and Sánchez-Díaz (2009).

Essential to the higher education system fulfilling its role in the economy and the society is that the curriculums have to underline the acquisition of competences and skills of non- academic nature skills, not being enough just the accumulation of academic knowledge. Some of these competences are specific to the area of studies that are concerned, but other skills are more general or "transverse", and are valid for a wide range of disciplines, as jobs in the modern economy and responsibility situations both private and professional in the society. (Pello Salaburu, 2011).

According to Weinert (1999), the concept of competence refers to an individually available collection of prerequisites for successful action in meaningful task domains or context. He suggests different ways in which competences have been defined, described or interpreted theoretically:

- General cognitive competencies, which focus on general competences including psychometric models of human intelligence and information processing models.
- Specialized cognitive competencies focusing on the categorization and characterization of competencies as clusters of cognitive prerequisites that must be available for an individual to perform well in a particular content area like solving mathematical problems. The performance-specific concepts of cognitive competence suggest that this approach has strong advantages over ability-centered definitions of competence because of its theoretical base and pragmatic applications (Leplatt, 1997).

- The competence-performance model, based on the theoretical paradigms in competence research derived from a distinction between competence and performance used by the linguist Noam Chomsky (1980).
- Modifications in the competence-performance model where it is assumed that the relation between competence and performance is moderated by other variables, for example, cognitive style, memory capacity, familiarity with the task situation, and other individual difference variables, differentiating on conceptual, procedural and performance competencies (Overton, 1985).
- Cognitive competence and motivational action tendencies defining competence as an effective interaction (of the individual) with the environment (White, 1959).
- Objective and subjective competence concepts which distinguish between "objective competence as performance and performance disposition that can be measured with standardized scales and tests" and "subjective competence as subjective assessment of performance relevant abilities and skills needed to master tasks and solve problems", Sembill (1992).
- Action competence includes all those cognitive, motivational and social prerequisites necessary and/or available for successful learning and action. Frequently action competence models include general problem-solving competence, critical thinking skills, domain-general and domain-specific knowledge, positive self-confidence and social competencies.
- Key-competencies which include basal competencies (e.g., mental arithmetic, literacy, general education); methodological competencies (e.g., planning for problem solving; competent use of a variety of media; computer skills, and so on), communicative competencies (foreign language skills; rhetoric; written and oral exposition skills; and so on); and judgment competencies (e.g. critical thinking skills; multidimensional judgments about one's own and others' performance). (Sternberg, 1996)
- Metacompetencies including declarative metacompetencies (experience and knowledge about different task difficulties; knowledge about one's own abilities, talent, knowledge, skills and cognitive deficits; knowledge about learning,

problem solving, and explanation regularities; knowledge about effective strategies for learning, remembering, problem solving, troubleshooting; and knowledge about techniques for mastering diverse tasks with available cognitive competencies) and procedural metacompetencies (strategies for organizing tasks and problems to make them easier to solve like organizing a task into a meaningful structure; breaking a text into smaller units that are easier to encode; marking and underlining important points to make them easier to remember; constructing memory cues and using them later).

Many different meanings exist depending on perspective and underlying objectives associated with the use of the term. Next, we expose a brief list of different definitions.

- Competencies are a generic body of knowledge, motives, traits, self-images and social roles and skills that are causally related to superior or effective performance in the job (McLlelland, 1973).
- Competence-based education tends to be a form of education that derives a curriculum from an analysis of a prospective or actual role in modern society and that attempts to certify student progress on the basis of demonstrated performance in some or all aspects of that role (Grant, 1979).
- Competence is a complex "knowledge in action", resulting from integration, mobilization and fitting of a whole of capacities and skills (being able to be of a nature cognitive, emotional, psychomotor or social) and of knowledge (declaratory knowledge) effectively used, in common contexts (Lasnier, 2000).
- A competence is the ability to meet individual or social demands successfully, or to carry out an activity or task. This external, demand-oriented, or functional approach has the advantage of placing at the forefront the personal and social demands facing individuals. This demand-oriented definition needs to be complemented by a conceptualization of competencies as internal mental structures: in the sense of abilities, capacities or dispositions embedded in the individual (Rychen & Tiana, 2004).
- Tuning Project (2003, p. 280) defines it as a dynamic combination of attributes with respect to the knowledge and its application, to the attitudes and responsibilities that describe the results of the learning of a determined program,

or how the students will be able to develop at the end of the educative process (González y Wagenaar, 2003).

- A person who has occupational competency has the necessary knowledge, skills and capacity to perform in a profession, is able to solve occupational problems in an autonomous and flexible manner and is able to contribute to his professional environment and the organization of work (Bunk, 1994).
- A complex structure of necessary attributes to perform in specific situations. This has been considered a holistic approach in the sense that it integrates and relates attributes and tasks, it enables several intentional actions to occur simultaneously and it takes into account the context and the culture of the workplace (Gonzci, 1996).

While qualification is a group of knowledge and capacities that individuals acquire during socialization and training processes, competency refers only to certain aspects of the store of knowledge and abilities: the ones necessary to achieve certain results demanded by a specific circumstance; the actual capacity to achieve (Mertens, 1996).

3.3 The competence-based assessment

The term performance-based learning represents a framework for learning systems that seeks to document that a learner has attained a given competency or set of competencies. Within a conceptual learning model, skills, abilities, and knowledge are developed through learning experiences. Competencies, then, are the result of integrative learning experiences in which skills, abilities, and knowledge interact to form a bundle of learning activities that have relation to the task for which they are assembled. Finally, demonstrations are the results of applying competencies. It is at this level that performance-based learning can be assessed (Voorhees, 2001).

Competence-based education has been historically based on a behaviorist model of training and learning, although a holistic approach is actually the practical design of learning processes and assessment procedures. In addition, while educators usually define competences as indicators of profits, knowledge and capacities, employers and economists, however, associate them to the performance, productivity, efficiency and professionalism. Consequently, there exist great difficulties to establish common guidelines for programme designing based on competences (Sánchez-Ruiz, Edwards and Ballester, 2006).

Competence-based performance, training, learning or education has also been a term discussed by quite a few authors. We reproduce some of their contributions:

» Glick, Henning, and Johnson (1975) established the competence based education as a data-based, adaptive, performance-oriented set of integrated processes that facilitate, measure, record and certify within the context of flexible time parameters the demonstration of known, explicitly stated, and agreed upon learning outcomes that reflect successful functioning in life roles.

» An important contribution from (Blank, W. 1982) draws a distinction between the basic characteristics that distinguish competency-based and traditional training programs.

What the students learn is based on outcomes that which describe what the students will be able to do upon completing the training program versus traditional program which are usually based on textbooks, reference material, course outlines or other sources built around chapters, units, blocks, and other segments.

The students learn with high quality and student-centered learning activities designed to help them master each task. Materials are organized so that each individual trainee may finish, slowdown, speed up or repeat instruction as needed to learn effectively. An integral part of this instruction is periodic feedback throughout the learning process with opportunities for trainees to correct their performance as they go. This is a very important and differentiating aspect that we consider essential to be core of the model of continuous assessment with active/retroactive components that will be developed in Chapter 4. On the other hand, traditional education is based on the instructor personally delivering most of the instruction through live demonstrations, lectures, and discussions and other instructor-centered learning activities.

The students advance task by task with enough time to master one task before they are allowed or forced to move on to the next one whereas with traditional methods the group moves on to the next unit after a fixed amount of time which maybe too soon or not soon enough for many individual students.

Feedback is provided just in time to each individual trainee while performing each task. Their mastering is compared to a preset, fixed standard and they are not allowed or forced to move on to the next unit after only marginally mastering or even 'failing' the current unit. We support this important characteristic by introducing the concept of targeting outcomes mastering.

Blank also exposes very interesting principles behind the competency-based learning which is based on ideas previously developed by other important authors like Carroll (1963), James Block (1970) and Bloom (1976) among others. Between these principles we find:

- Any student in a training program can master most any task at a high level of mastery if provided with high-quality instruction and sufficient time.
- A student's ability for learning a task need does not predict how well the student learns the task.
- Individual student differences in levels of mastery of a task are caused primarily by errors in the training environment, not by characteristics of the students.
- Rather than being fast or slow learners, or good or poor learners, most students become very similar to one another in learning ability, rate of learning, and motivation for further learning when provided with favorable learning conditions.
- We should focus more on differences in learning and less on differences in learners.
- What is worth teaching is worth learning.
- The most important element in the teaching-learning process is the kind and quality of instruction experienced by students.

These principles aim us to implement our computational model of active/retroactive assessment as they consider the personal skills set of each student at the same time as it promotes an individualization of the workloads in order to achieve the collective objectives.

We also agree with Blank's assertion about the fact that dropout rates are usually lowered when students get hands-on experience and can experience a high level of success without the pressure of competing with other students for grades. Besides the subject, programme can almost run itself reducing the continuous necessity of the instructor presence.

» Foyster (1990) makes a study about what is involved in competence-based teaching and learning and describes some essential characteristics of the competency-based programs.

- An occupational/job analysis was carried out after the programme has been running for some time.
- There is a focus on competencies rather than the ability to pass exams.
- Learners have access to statements of the competencies.
- There are appropriate assessment procedures promoting the achievement of competences.
- The positive results are reported as competencies achieved.
- Detailed records are maintained to facilitate the progression over the learner's career and development of programs.

His study also deals with many other characteristics marked as desirable:

- There should be a statement of criteria for each competency.
- There should be careful selection of competencies for each specific program.
- There should be an integration of theory and practice, with an emphasis on applications.
- The method of instruction should involve mastery-learning methods and should include immediate and comprehensive feedback to learners.
- Criterion-referenced testing of skills already possessed on entry should be available to learners.

» Assessment of competencies is really a complex problem due to the fact that competencies comprises a complex integration of knowledge and skills (Van Merriënboer, Van der Klink and Hendriks, 2002) and it is necessary to assess with several assessment methods. Therefore classic assessment methods should not be ignored and discarded beforehand, because any method may contribute to the complex job of determining whether a learner has acquired a competency.

Assessing competencies through the execution of very different and many activities try to assure that there all the aspects of the competences acquisition are covered.

The evaluation of a competence is most appropriate if it is assessed in a comprehensive way and not separately for each of their elements (Tardif, 2006). This method is closer to deal with the so called *depth learning* (Villa, 2008). A method of evaluation that integrates all the competences promotes more appropriate learning and consistent of competencies (Rust, Price and O'Donovan,2003).

3.4 Mathematical competences

3.4.1 Niss' eight competences

We are going to focus our study on a computational algorithm for continuous assessment around the concept of mathematical competencies following the KOM project by Niss which is the core of this work and a reference to follow. We summarize and reproduce part of this dissertation to compile the study of mathematical competences.

The mathematical competence implies to have the knowledge of understand, do, use and have an opinion about mathematics and mathematical activity in a variety of contexts where mathematics plays or can play a role which implies the presence of a variety of procedural knowledge and concrete skills within the mathematical field. These prerequisites are aspects of a general mathematical competence.

Niss developed a list of eight core competencies which are mutually connected and none of them can be reduced to the remaining ones and allow us to think about them as a set of well-defined dimensions, which together encompass mathematical competence.

The eight competences can be clustered into two groups. The first cluster deals with the ability to ask and answer questions in and with mathematics and covering the first four competencies, that is, the ability to pose mathematical questions and be aware of the kinds of answers available, answer such questions in and by means of mathematics and understand, assess and produce arguments to solve mathematical questions.

The second cluster refers to the ability to deal with mathematical language and tools, and covers the remaining four competencies implying the ability to deal with different representations of mathematical entities and situations, to deal with the special symbolic and formulaic representations in mathematics and be able to communicate in, with and about mathematics as well as be able to make use of the diverse technical aids for mathematical activity.

From now on we will use the notation Mcn to refer to one of the eight competences within one of the two clusters aforementioned (c=1,2; n=1,2,3,4).

3.4.1.1 M11: Thinking mathematically

This competence includes the recognition of mathematical concepts and an understanding of their scope and limitations as well as extending the scope by abstraction and generalization results. The core of this competency is the nature of mathematical questions and answers and not the content of questions and answers.

To think mathematically implies being mindful of mathematical questions and to demonstrate the ability to pose such questions and an insight into the types of answers that can be expected; being able to exert the necessary and sufficient conditions to characterize a mathematical object and understanding and handling the extent and limits of given mathematical concepts.

3.4.1.2 M12: Reasoning mathematically

This competency includes the ability to understand the notion of proof and to recognize the central ideas in proofs. It also includes the knowledge and the ability to distinguish between different kinds of mathematical statements.

To reason mathematically implies the ability to follow and assess mathematical reasoning and to know what mathematical proofs are and how they differ from other kinds of mathematical reasoning, following and assessing chains of mathematical arguments of different types and to contrive formal and informal arguments and transform heuristic reasoning into valid proofs.

The ability to carry out calculations or routine operations deals with other competencies as posing and solving mathematical problems. From the point of view of M12 we refer to the fact of proposing or activating the operation wheter this activation demands creativity, analysis or overview.

3.4.1.3 M13: Posing and solving mathematical problems

On the other hand, this competence comprises the ability to formulate and define different kinds of mathematical problems and on the other hand the ability to solve them in a variety of ways.

Niss emphasizes about the differences between M13 and M11 as "being able to solve a mathematical problem" is not included in the competency of "mathematical thinking" and being able to distinguish between definitions and theorems in the mathematical thinking competency is not part of mathematical problem tackling competency.

3.4.1.4 M14: Modelling mathematically

This competency deals with the ability to analyze the foundations and properties of existing models as well as the ability to perform active modelling.

It implies to be able to work with a mathematical model and interpret some elements and results in terms of the area or situation that are supposed to model, validate and analyze offering a critique of its results.

It also deals with having the ability to perform active modelling mathematising and applying it to situations beyond mathematics itself translating reality into mathematical structures.

3.4.1.5 M21: Representing mathematical entities

This competency includes the ability to understand and use mathematical representations, understanding and utilizing different types of representations of mathematical objects including symbolic representations like algebraic, visual, geometric, graphic, diagrammatic or tabular and managing the interrelationships between various representations and choosing and switching between different forms of representation, according to situation and purpose.

To represent mathematical objects is one of the most important competencies in mathematics and has a close connection with M22 from which it differs because this one deals with the use of mathematical symbols and formal language whereas M21 is about understanding the representations and the connections between them and knowing the strengths and weaknesses of the each individual representation.

3.4.1.6 M22: Handling mathematical symbols and formalism

It includes the ability to use and manipulate symbolic statements and expressions according to the rules that implies being able to use symbols and formal language; establishing the connections between the mathematical symbolic language and natural language and having an insight into the nature of the rules of formal mathematical systems.

3.4.1.7 M23: Communicating in, with and about mathematics

This competency includes the ability to understand mathematical statements made by others and to express oneself mathematically in different ways, studying and interpreting others' written, oral or visual mathematical expressions.

On the other hand it implies to have the ability to express oneself with different levels of theoretical or technical precision about mathematical matters, either written, oral or visual, to different types of audiences.

3.4.1.8 M24: Making use of aids and tools

It includes knowledge about the aids and tools that are available as well as their potential and limitations, including arithmetic programs, graphic programs, computer algebra and spreadsheets, tables, slide rules, compasses, etc. The competency is about being able to deal with and relate to such aids.

3.4.1.9 Other sets of competences

The eight basic competences are a set of mathematical competences covering aspects of a general mathematical competence. Other sets of competences have been defined or proposed in order to achieve similar objectives.

For instance, García, García, Martín, Rodríguez, de la Villa (2012) have proposed the following set of competences:

- GC1: Self Learning.
- GC2: Critical Thinking.
- GC3: Use of ICT.

- GC4: Problem solving.
- GC5: Technical Communication.
- GC6: Team work.

Where GC1 refers the ability to engage in independent life-long learning, while analyzing, synthesizing and applying relevant information are referred as critical thinking (CG2). CG3 deals with the ability to use modern technologies of communication. The next two CG4 and CG5 are similar to M13 and M23. Finally CG6 is related to the ability to function effectively as a member of a multidisciplinary team.

3.4.2 Competences dimensions

Finally, the KOM project introduces three different dimensions for specifying and measuring progress in mastering the competences:

3.4.2.1 Degree of coverage

It is used to indicate the extent to which the person masters those aspects that characterize the competency, i.e. how many of these aspects the person can activate in the different situations available, and to what extent independent activation takes place.

3.4.2.2 Radius of action

It is the spectrum of contexts and situations in which the person can activate the competency.

For example, if a person can solve problems dealing with arithmetic, algebra, geometry and probability theory, he or she has greater radius of action than a person who can only manage arithmetic and algebra.

3.4.2.3 Technical level

The technical level of a person's competency is determined by how conceptually and technically advanced the entities and tools are that can be activated in the relevant competency.

For example, a person who can sketch graphs for real functions of one variable, but not for real functions of two variables, has a representing competency at a lower technical level than the person who can attain both.

3.4.3 Mathematical competences in OECD PISA

3.4.3.1 Introduction

The Niss competences overlap but emphasizes different aspects and is therefore separated. However, OECD PISA (2009) does not test the mathematical competences individually due to this overlap arguing that when using mathematics, it is usually necessary to draw attention simultaneously on many of them, so that any effort to assess individual ones is likely to result in artificial tasks and unnecessary compartmentalization. Anyway, we are going to introduce in Chapter 5 a method of binary assessment based on the evaluation of the eight core competencies.

In order to specify the degree of coverage, OECD PISA (2009) describes three clusters that will be expose in the following sections.

3.4.3.2 The reproduction cluster

The mathematical competencies in this cluster involve the reproduction of practiced knowledge, including the knowledge and skills most commonly targeted on standardized assessments and classroom tests. These are knowledge of facts and of common problem representations, recognition of equivalents, recollection of familiar mathematical objects and properties, performance of routine procedures, application of standard algorithms and technical skills, manipulation of expressions containing symbols and formulae in standard form, and carrying out computations.

The eight competences play out as:

- M11: distinguishing between definitions and assertions; understanding and handling mathematical concepts in sorts of contexts in which they were first introduced or have subsequently been practiced.
- M12: following and justifying standard quantitative processes.
- M13: formulating problems by recognizing and reproducing practiced standard pure and applied problems and solving such problems by invoking and using standard approaches and procedures.
- M14: recognizing well-structured and known models and interpreting back and forth between such models and reality.
- M21: decoding, encoding and interpreting practiced standard representations of well-known mathematical objects. Switching between representations is

involved only when the switching itself is an established part of the representations implied.

- M22: decoding and interpreting routine basic symbolic and formal language practiced in well-known contexts and situations.
- M23: expressing oneself orally and in writing about simple mathematical matters, such as reproducing the names and the basic properties of familiar objects.
- M24: knowing about and being able to use familiar aids and tools in contexts, situations and ways close to those in which their use was introduced and practiced.

3.4.3.3 The connections cluster

The connections cluster builds on the reproduction cluster by applying problem solving to situations that are not routine but still involve familiar or quasi-familiar settings.

The eight competences play out as:

- M11: playing like in reproduction cluster but understanding and handling mathematical concepts in contexts that are slightly different from those in which they were first introduced or have subsequently been practiced.
- M12: following and assessing chains of mathematical arguments of different types and possessing a feel for heuristics
- M13: posing and formulating problems beyond the reproduction of practiced standard pure and applied problems and solving more independent problem-solving processes in which connections are made between different mathematical areas and modes of representation.
- M14: translating reality into mathematical structures in contexts that are not too complex but nevertheless different from what students are usually familiar with.
- M21: decoding, encoding and interpreting familiar and less familiar representations of mathematical objects
- M22: decoding and interpreting basic symbolic and formal language in less well-known contexts and situations.

- M23: understanding and expressing oneself orally and in writing about mathematical matters ranging from reproducing the names and basic properties of familiar objects and explaining computations and their results in several ways.
- M24: knowing about and using familiar aids and tools in contexts, situations and ways that are different from those in which their use was introduced and practiced.

Connections cluster introduces in all competences the ability to extend the scope of the concepts.

3.4.3.4 The reflection cluster

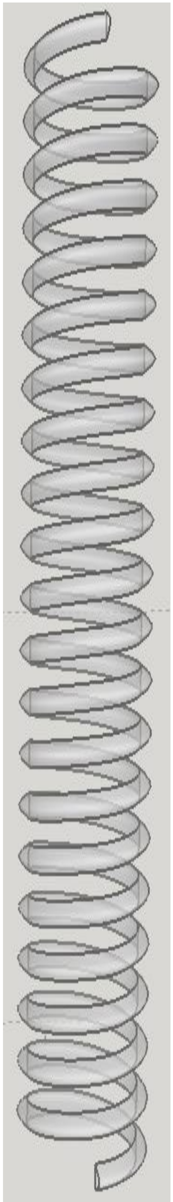
An element of reflectiveness in included on the part of the student about the processes needed or used to solve a problem. They relate to students' abilities to plan solution strategies and implement them in problem settings that contain more elements than those in the connections cluster.

Beyond the connections cluster implies:

- M11: understanding and handling mathematical concepts in contexts that are new or complex; understanding and handling the extent and limits of given mathematical concepts and generalizing results.
- M12: reasoning, following, assessing and constructing chains of mathematical arguments of different types.
- M13: posing and formulating problems well beyond the reproduction of practiced standard pure and applied problems in closed form and more original problem-solving processes in which connections are being made between different mathematical areas and modes of representation.
- M14: translating reality into mathematical structures in contexts that may be complex or largely different from what students are usually familiar with and monitoring the modelling process and validating the resulting model.
- M21: involving the creative combination of representations and the invention of non-standard ones.

- M22: decoding and interpreting symbolic and formal language practiced in unknown contexts and situations and the ability to deal with complex statements and expressions and with unfamiliar symbolic or formal language.
- M23: understanding and expressing oneself orally and in writing about mathematical matters that include complex relationships.
- M24: knowing about and using familiar or unfamiliar aids and tools in contexts, situations and ways that are quite different from those in which their use was introduced and practiced. It also involves knowing about limitations of aids and tools.

3.4.4 An example



Here we reproduce a mathematical problem proposed to the first year students in mathematics classes at Aerospace Engineering in which we detail how the different mathematical competences are worked out.

In a cylinder whose radius and height are 16 cm and 50 cm respectively we wish to coil up a cupper cylindrical cable of 4 mm of radius in such way that it does not exceed any of its bases.

Assuming we want to have a natural number of spires greater than 2:

- *Find if there is some integer number of mm between spires so that we use as little amount of cable as possible and write down the corresponding number of spires that there are.*
- *Write down the equation of the curve defined by the skeleton cable curve, i.e. the one that forms the central axis of the cable.*

In case we are to coil as much cable as possible round the cylinder, without overlapping, find out:

- *The length of cable used.*
- *The number of spires (nor necessarily integer) up to hundredths.*
- *The coordinates of the ending point of the skeleton cable curve.*

This problem tries to stimulate the development of the different mathematical skills in the student. The context in which the problem appears is in the resolution of problems of lengths of curves but it is requested to answer some additional questions that are related but that are not solved by the theory of calculus of curves' lengths.

The first questions deals with the knowledge about integers and their relationships and it also involves an optimization problem.

Let us suppose we have n spires that imply that we have n spaces equally distributed between spires. Let d be the space between spires. Then, the problem consists in finding the smallest integer d that satisfies the equation:

$$8(n+1) + nd = 500$$

Or equivalently

$$d = \frac{492 - 8n}{n} = \frac{492}{n} - 8$$

Then, n must be the smallest positive divisor of 492, with n > 2, in order to get the minimum number of spires. Thus, n=3 and d=156mm.

Regardless of the simplicity of the question, its resolution implies to think about integer (thinking) and propose the corresponding equation (solving problems) and to go on with a chain of reasoning in order to formulate the equivalent problem (reasoning) as "to find the first positive integer divisor of 492" which encompasses finding a given integer and a minimum., i.e. the essence of the question.

The second question implies to create a model (modelling) and a system of representation (representing):

The projection of the helix's axe on the plane OXY is a circumference of radius 16.4 cm and the height is proportional to the angle α described by the projection of the cable. The students have to realize that they have to model the equation of the axis of the cable, that the initial position is the point (16.4,0,0.4) assuming the coordinates origin in the center of the cylinder's basis, and in each complete spire the height is incremented by 15.6+.8 = 16.4cm. Then, the parametric equations of the helix are:

$$\begin{cases} x = 16.4\cos\alpha \\ y = 16.4\sin\alpha \\ z = 0.4 + \dfrac{16.4}{2\pi}\alpha \end{cases} \quad \alpha \in [0,6\pi]$$

In order to get the expression which represents the curve it has been necessary to handle mathematical symbols (handle symbols) and also to think and reason mathematically (thinking and reasoning).

The last part of the problem implies to reproduce well-known procedures which have been seen and practiced by the students in lectures and laboratory practices, but it also implies to make an extension of the model designed in the first part of the problem.

If the cable coils round the cylinder without overlapping, then d=0 and the parametric equations are:

$$\begin{cases} x = 16.4\cos\alpha \\ y = 16.4\sin\alpha \\ z = 0.4 + \dfrac{0.8}{2\pi}\alpha \end{cases} \quad \alpha \in [0, \alpha_{max}]$$

where $\alpha_{max}=123\pi$ is obtained when the cable reach the top of the cylinder, i.e. for z=49.6. Then, there are 61.5 spires and the cable ends in the symmetric point of the initial point respect the cylinder's center, exactly in (-16.4, 0, 49.6).

The length of the cable is the length of one spire multiplied by the number of spires:

$$L = 61.5\int_0^{2\pi}\sqrt{\left(\frac{dx}{d\alpha}\right)^2 + \left(\frac{dy}{d\alpha}\right)^2 + \left(\frac{dz}{d\alpha}\right)^2}\, d\alpha = 6337.41\ cm$$

To reformulate the parametric equations implies an extension of the primary written equations (modelling, representing and reasoning). The calculus of the cable's length implies the reproduction of calculus' procedures (solving problems).

Finally, writing or explaining the solution implies the ability to communicate and maybe the use of tools if the calculus is supported by calculators or computer programs.

As we have seen, improving several competences is embedded within the execution of activities when these are been carefully designed in order to force students to think and reason instead of doing a simple reproduction of procedures. Clearly, to designing this type of activities implies an intensive time consuming task.

3.5 Activities

3.5.1 Characterization and their impact on competences

Following Niss (2009, Chapter 9), a competency is an insight-based readiness to act and is manifested in mathematical activities, there so a mathematical activity consists in a set of conscious and goal oriented mathematical actions in a situation.

A mathematical activity can be, for example, to solve a pure or applied problem, to develop a mathematical model, to communicate or present a mathematical result, to demonstrate a theorem, to use a calculator or computer program, to attend lectures, etc.

Executing a mathematical activity implies the exercise, or may be the improvement, of one or more basic mathematical competences and it is possible to detect and judge the competencies of the person concerned in relation to the specific activity execution.

The study of which person's competencies actually brings into play in a given activity can be done only if we may detect a valid, reliable and clear content of each competency in a person's actions while carrying out the activity and the results of such actions, i.e. if we have a reliable method to assess the result of the activity execution.

That said, a given activity will probably involve the use of a subset of competencies and different activities will probably involve the use of different sets of competences. Then, if we find a collection of mathematical activities of different nature, we could master a comprehensive representation of the full set of mathematical competences.

Our objective is to find a way of evaluating the individual person's mastery of a given mathematical competency and to get an overall picture of the respective person's mathematical competency profile owing to the fact that competencies are achieved by the execution of mathematical activities. Niss defines the task to be down by each instructor as follows:

- To find collections of mathematical activities suitable for a valid, reliable and clear way of demonstrating the presence of a given mathematical competency in a person involved in the activity, making possible to detect and judge the extent and depth of competency mastery in the way it is expressed in the individual activity.

- To find a set of mathematical activities which together are suitable for a valid, reliable and clear way of illustrating a person's total mathematical competency profile.
- To find a way of identifying, characterizing and judging progression in a person's mastery of one or more of the mathematical competencies.

Making use of the three dimensions in a person's mastery of a competency, the task must be defined to detect and judge the degree of coverage, radius of action and technical level respectively in such a way a person can activate a given mathematical competency in a variety of mathematical activities.

The first two parts of this task involve finding out the state of a person's competency mastery and the third part involves describing the development over time of this competency mastery. It is vital to remember that in this task one should not only think on the final assessment (summative), but also think of supplying information about and for the individual student (formative assessment) and for the teacher about the status and development of their activity.

In fact, proposing sets of activities of already covered topics along a sequence of intervals of time will help to consolidate the acquired knowledge, skills and competences (Hoffmann, 2011a).

In the following paragraphs we reproduce a list of different types of activities and their possible relationships with the eight mathematical competences.

3.5.2 Lectures

Lectures are still the main form of teaching mathematics in higher education. Accordingly Slomson (2010) lectures have the following characteristics:

- They introduce to students new material
- The lecture is the primary route by which student are exposed to this material.

- There may be some interactions with the audience but the lecturer sets the agenda or syllabus and the main aim of the lecturer is to transmit a predetermined amount of material.
- The purpose of a mathematical lecture is to contribute to the learning of mathematics by the students.

There might also be specific lectures on mathematical modelling or problem solving which are dedicated to addressing specific competencies but most lectures cover the principal concepts and procedures in a course programme.

A lecture can be considered as an activity from the point of view of the students since they have to attend and to pay attention to the lecturer. It is an instrument to introduce new concepts as well as to introduce procedures and techniques to reason mathematically and solve problems.

Lectures can contribute to the acquisition of the eight mathematical competences since they cover different aspects of the learning process despite the students could be in a passive role. *Students learn both passively and actively. Passive learning takes place when students take the role of "receptacles of knowledge"; that is, they do not directly participate in the learning process. Active learning is more likely to take place when students are doing something besides listening* (Ryan and Martens, 1989). Following Bonwell (1991) active learning promotes the participation of the students in lectures:

- Students are involved in more than listening.
- Less emphasis is placed on transmitting information and more on developing students' skills.
- Students are involved in higher-order thinking (analysis, synthesis and evaluation).
- Students are engaged in activities (e.g., reading, discussing and writing).
- Greater emphasis is placed on students' exploration of their own attitudes and values.

But learning is also acquired by associating within a context, training, practicing and by creativity. Creativity have been defined as the process of transfer rules from one context to a completely different one. With previous knowledge, skills and competences, creativity augment and enhances the richness of facts (Hoffmann, 2011b),

Lectures contribute to develop the eight base competences. Following Alpers and Demlova (2012):

- M11: Lectures contribute to develop and apply mathematical thinking to other disciplines. For example, matrix theory is a very useful tool developing program computer. So, teacher could encourage students to think mathematically when they apply matrix properties to code programs.
- M12: The instructor explains mathematical reasoning when he demonstrates theorems or selects a method of solving a problem. Quire likely, the students cannot see the whole process of creation or the reasoning chain to produce the results. But the lecturer should provide enough explanatory material.
- M13: The students do not see the real problem-solving process but an elaborated version. The lecturer usually outlines the strategies applied in order to match the background theory with the objective that students become competent in solving other similar problems.
- M14: Again, lectures have restrictions to show a complete modelling process except for simple examples. Anyway, the lecturer decides what kind of situation can be modelled with the mathematical concepts used.
- M21: Lectures can show the utility of different representations and how to switch between them as for example the different types of equations of a straight line.
- M22: Lectures are a good instrument to teach examples of the correct use of symbols and formal language in mathematics. While lecturers demonstrate theorems or solve problems, they show how to use symbols and introduce new components of the formal language.
- M23: Communication is one of the major competence improvement in lectures on the student's side because of the nature of traditional lectures. There the teacher exposes results and mathematical theories while the students gains in communication skills emulating lecturer presentations.

- M24: The lecturers can explain the basic use of tools and aids that students should handle when working in assignments or lab practices. For example, computer mathematical programs are good candidates to be introduce in lectures and used in laboratory practices.

Introducing active learning techniques in lectures may be interesting in order to increment the student's participation in classroom. Some important quotes in this sense are:

- Learning is not a spectator sport. Students do not learn much just by sitting in class listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves (Chickering and Gamson 1987, p.3).
- Students learn what they care about and remember what they understand (Ericksen 1984, p. 51).
- When students are actively involved in learning, they learn more than when they are passive recipients of instruction (Cross 1987, p. 4).
- Students learn by becoming involved. Student involvement refers to the amount of physical and psychological energy that the student devotes to the academic experience (Astin 1985, pp. 133-34).

Lectures are a desirable approach in the classroom and a lecturer can:

- Communicate the intrinsic interest of the matter differently from any other media
- Provide students with a thoughtful, scholarly role model to emulate.
- Describe topics on details that are otherwise unavailable, such as original research or current developments not yet published in traditional textbooks.
- Organize material in ways to meet the particular needs of a given audience.
- Efficiently deliver large amounts of information if certain conditions are met (Chism et al. 1989).

Lectures are activities that might sound difficult to introduce as an assessment procedure given that to attend – or to be "in" – a lecture does not guarantee the acquisition of knowledge or training experience. Even in that assumption it is difficult to give feedback to the student about the degree of his/her positive use of the class.

However, some initiatives could make feasible both things by looking for a more strong engagement of the students and obtaining a feedback about their participation. The use of electronic voting systems (EVS) in lectures (King, Davis, Robinson and Ward, 2008) make lectures more interactive and get students more engaged introducing multiple choice questions in real time and collecting the answers with adequate software. The identification of devices make feasible to give positive feedback to students according to their responses or if such identification happened not to be feasible, we would be able to give an aggregated feedback.

According to the authors, the key benefits of EVS use that participants identified are:

- EVS can be used as a formative assessment tool, which in turn can help identify the areas where students are struggling.
- EVS use promotes interactive engagement including student-to-student interactivity.
- EVS Increases student participation and contribution levels.
- Its use can catalyze student motivation and interest.
- It can be deployed for contingent teaching purposes.

3.5.3 Assignments

By assignments we refer to those tasks like development of theoretical and problem-solving questions with or without the use of technology tools that the students have to use on their own out of the class.

These type of activities are related to the content of lectures and they have to be executed immediately after the lectures' conclusion in order to reinforce the concepts learned and be able to reproduce on one hand the procedures and methods to solve repetitive problems and, on the other hand to improve the reasoning and thinking abilities with the theoretical concepts background.

Assignments may be considered as a form of self-regulated learning since students have to deal by themselves with the task execution and do it based on the knowledge acquired in class.

According to Pintrich (2004), there are four general assumptions of a self-regulated learning perspective:

- The learning is active and constructive. Learners are assumed to construct their own meanings, goals, and strategies from the information available in the external environment as well as information in their own minds or the internal environment (Biggs, 1993; Vermunt, 1996)
- The potential of control. The learners can potentially monitor, control, and regulate certain aspects of their own cognition, motivation, and behavior as well as some features of their environments.
- Learners can set standards or goals to strive for in their learning, monitor their progress toward these goals, and then adapt and regulate their cognition, motivation and behavior in order to reach their goals (Vermetten et al., 1999).
- Self-regulatory activities are mediators between personal and contextual characteristics and actual achievement or performance. That is, it is not just students' characteristics that influence achievement and learning directly, nor just the contextual characteristics of the classroom environment that shape achievement, but the students' self-regulation of their cognition, motivation, and behavior that mediate the relations between the person, context, and eventual achievement.

Assignments contribute to develop the eight basic competences. Again, following Alpers and Demlova (2012):

- M11: Assignments contribute to improve mathematical thinking in tasks where students have to work and solve questions that are of practical interest, applying the background obtained in lectures or through other activities of study.
- M12: The execution of standard and repetitive task strengthens the processes of mathematical reasoning but in a restricted form. More open assignments will contribute the development of chains of logical arguments. In the previous

example of the cable, to calculate the equation of the axis of the cable develops the geometric reasoning to take in consideration the initial spire of the first point of the curve and the separation on the surface of the cylinder due to the thickness of the cable.

- M13: Standard problems can be learned using standard tasks. For example the calculus of the cable's length resolving the appropriate integral. More open assignments imply a deeper reflection on the underlying knowledge to tackle these kind of problems.
- M14: Standard tasks are restrictive to improve the mathematical modelling using given mathematical models solves only well-defined mathematical problems. Broader activities such as projects and tutorials are the most suitable to develop this competency.
- M21: In repetitive tasks the students can switch between different representations and they also can be encouraged to use the more appropriate representation.
- M22: Standard tasks are a good instrument to train students in using mathematical symbols and formal language and get the desired fluency.
- M23: Written assignments improve the capacity to communicate due to the need to state clearly mathematical arguments. On the other hand, if the students have to work in groups or make public presentations, they can also improve the oral communication.
- M24: The use of aids and tools can be exercised when the assignments include the use of these tools like computer programs or other appropriate devices.

Some authors (Mínguez, Llobregat-Gómez, Roselló, and Sánchez Ruiz, 2015a). state that in active learning the students get activities, tools and approaches that together with their motivation, attention, emotions and intuition makes from the learning a creative attitude. The working memory, that is, the memory needed in the realization of a process (Reid, 2009) together with the capacity to apply many operative memories to the same object (Marina, 2011), makes that the new ideas are linked together in a complex matrix so that the learner can make sense of how everything fits, applying then that knowledge to the new situation (Reid, 2009).

In homework assignments there may be some doubt about the true authorship in the executed activities. The goal of the assignments is the consolidation of knowledge and the improvement of the students' fluency in the resolution of problems with the added value of facing by themselves alone the execution of activities as well as generating the capacity of self-assessment and self-learning.

Even so, from a point of view of obtaining a grade in the evaluation process it is necessary to ensure that the students have made the work by themselves and they have acquired the required skills. A variation that may be introduced in this type of activity consists of complementing the execution of these activities with an oral presentation or by introducing a certifying multiple-choice evaluation test.

In this case the students may be given a collection of activities to execute. They can review the material initially generated in class, make use of tutorials and group discussion with their peers until the completion of the work in a given period of time. Then, the students deliver their work to the teacher and they are requested to do a multiple-choice test in a controlled environment and in a short period of time, 10 to 15 minutes, with issues closely related to the collection of activities. Answering the test supposes neither an added complexity nor new developments but simply a selection of the obtained results or underlying theoretical questions that necessarily have had to be used to do the homework assignments.

In addition, the scoring system of the multi-choice test assign positive scores to correct answers, no punctuation in question that have been left blank and negative scores for incorrect answers. Under the assumption that the students have done the assignment by themselves out of the class, they should have to know the correct answers. As Velichová (2012) states, all incorrect hits can be rewarded by negative points. In this way, any risk and unreasonable guess might be eliminated, as minus points influence the total test score rather negatively. The total balance of points achieved then represents a more objective view, and gives a better insight to the real understanding of the core mathematical concepts in the broad sense.

This procedure adds a plus of authorship certification and produces a more reliable assessment process.

3.5.4 An assignment example

In order to illustrate the aforementioned procedure, we reproduce a mathematical problem included in an assignment as a collection of activities to be resolved out of the classroom in the first year at BEng Aerospace Engineering UPV, during 2014-2015, which results can be found in Llobregat-Gómez, Mínguez, Roselló and Sánchez Ruiz (2015b).

The problem to be studied and solved included in the assignment was:

- Consider the parabola $y=x^2$ and the straight lines y = x/2, x=1 and x=3. Find the volume of the solids of revolution generated when the region enclosed rotates: (a) around OX, (b) around x=-1. (c) Make a sketch and write down two possible names describing these solids of revolution.

Later, in the multi-choice test done in the classroom (controlled environment) there are some questions related to the previous problem, namely:

- Let us observe the regions A and B covered between the parabola $y=x^2$ and the straight line x=2. When rotating around the axis OY, what is the relationship between the volumes generated by the regions A and B?

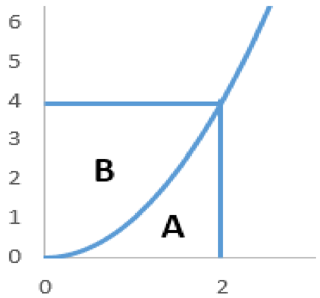
  a) VA > VB

  b) VA = VB

  c) VA > VB/2

  d) None of the previous answers is correct.

- The volume generated by the region B rotating around OY is calculated using the expression:



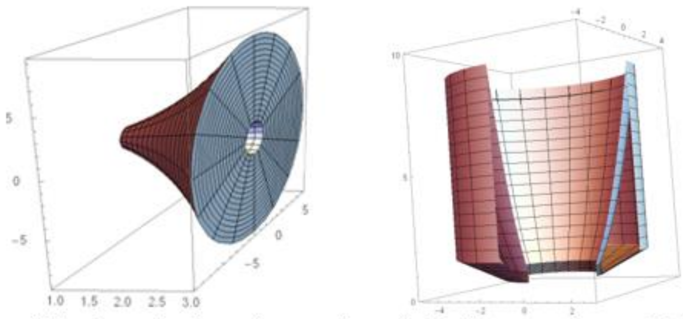
  a) $\pi \int_0^2 x^4 dx$ c) $\pi \int_0^4 (4-y)^2 dy$

  b) $\pi \int_0^4 y^2 dy$ d) $\pi \int_0^4 (4-y) dy$

- Given the previous volumes, what is the value of the expression $e^{\frac{V_A+V_B}{16}i}$:

  a) 1 b) -1 c) e^{π} d) i

The solids of revolution mentioned in this exercise are represented in the next picture:



Solids of revolution: a) around OX (left); b) around x= -1 (right)

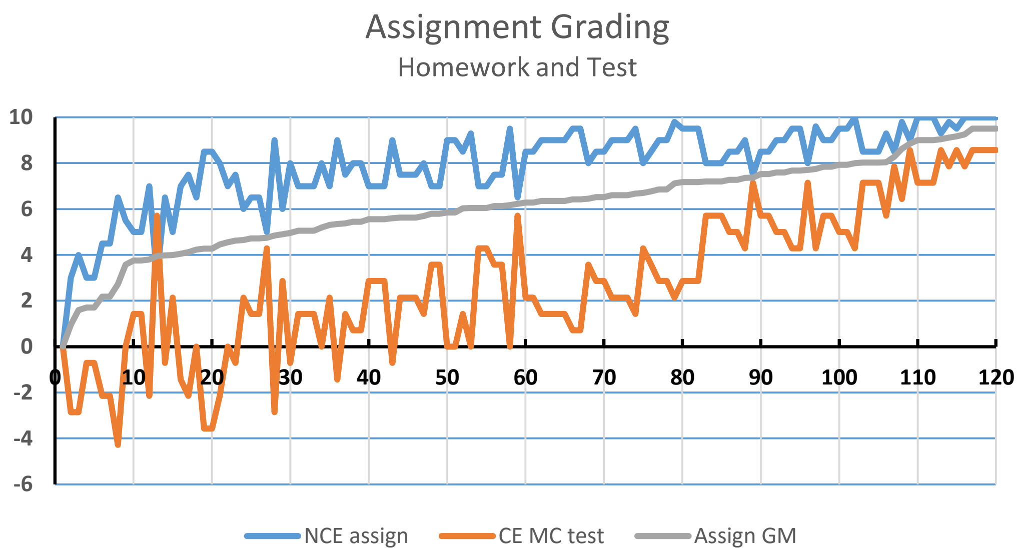
From the 120 students in the course, 22 did not do draw any sketch or give any name to the solid a) and 20 of them did not do anything at all with the solid b). Some students just made a sketch and from those 37 students did not dare to give any description of solid a) while 38 students gave no name to solid b).

Some of the answers provided to the solid of revolution a) were truncated paraboloid lamp with cone inside, lamp, trumpet, megaphone, loudspeaker, bowl, volcano, “firstone”,.. And some of the answers provided to the solid of revolution b) were truncated cylinder with internal paraboloid ramp, stadium-bull arena, funnel, bucket, antenna, bowl, cup-like, “secondone”,…

As we see there were some geometrical descriptive attempts as well as shape related ones, and some very little informative in what concerns shape or form as the aforementioned last ones.

Since non-environmentally controlled exercises are always difficult to assess, students were requested to do a multiple-choice test at class related with the type of exercises they had been doing during one week.

Next figure gathers the result of each student sorted ascending by the global mark obtained. With very rare exceptions most of them performed better in the non-controlled environment (NCE) than at class under controlled environment (CE). The assignment global mark was obtained by weighing these two results.



In some very few cases we found a huge divergence in the performance in NCE and at class that leads to think that they received some kind of help.

And it was strange but there was a case in which they got a better result at class than under NCE, perhaps because they did not pay the assignment the due time or did not present it properly as this was an aspect which they had been told that would be taken into account as well.

In the multiple-choice test under CE students were allowed even to look at their home assignments, thus it was not a standard multiple-choice test. For that reason students knew that they would be awarded with the same positive (negative) absolute input in case of success (failure), with 0 input in case of no answer.

This is why there were some students who got a negative grading in the multiple-choice test taht somehow compensated (35% of weigh) the probable excessive value given to the NCE (65%).

3.5.5 Mathematics laboratories

By mathematics laboratories, we mean learning scenarios where students work in a PC laboratory on tasks requiring the use of mathematical software such as numerical programs. In such laboratory sessions, students practice the usage of the programs and learn how they can be used for standard tasks.

Mathematics laboratories follow a similar pattern to the assignments regarding the contribution to develop the eight base competences emphasizing the use of tools and aids.

In assignments there is not a fixed pattern in the involvement of the different competences since they have a great dependence of the type of problems to be solved, from simple repetitions of calculus procedures to the resolution of theoretical questions of major complexity. In mathematical laboratories the orientation is primarily based on calculation procedures with a special relevance in the use of tools such as scientific calculation programs:

- M11: Similar to assignments.
- M12: Solving calculus problems with the aid of scientific programs does not always follow the same schemes as the classical written resolutions. Therefore, a certain reasoning ability is required to split into subtasks the strategy of problem solving calculation.
- M13: Similar to assignments.
- M14: Work with scientific programs gives the opportunity to evaluate, to control and to monitor mathematical models and other technical disciplines as well as to experiment with different values of parameters or new variables. It also provides skills to develop new models from existing others.
- M21: Similar to assignments.
- M22: Again, scientific calculation programs require a formalization and ad hoc use of symbols imposed by the tools' syntax. Therefore, it is a very specific use of this competence.
- M23: If the students have to work in groups or make public presentations by means of interface tools, these ones promote another form of communication that overlay the specificities of the tools with the proper ones of problem solving.
- M24: This competence is clearly involved in the resolution of problems by means of scientific programs. There are a great variety of tools to develop activities in the field of engineering, mathematics, graphic design, electronics, mechanicals, etc.

3.5.6 Flipped learning at Math Labs

The Laboratory Practices (LP) are a good candidate to apply the flipped classroom methodology with the students as done at ETSID, Univesitat Politècnica de València, where it has been developed a new approach to carry out the Math Lab sessions that students must take in order to minimize dropouts and losses of interest by maintaining them most active throughout the course. Lab sessions have been changed from a traditional system to another one based on a flipped classroom methodology. (Mínguez, Moll, Moraño, Roselló and Sánchez Ruiz, 2014).

As Bilton (2014) states, the flipped classroom is an instructional methodology and a type of blended learning that delivers instructional content, often online, outside of the classroom and it moves activities, including those that may have traditionally been considered homework into the classroom. In a flipped classroom model, students watch online lectures, collaborate in online discussions, or carry out research at home and engage in concepts in the classroom with the guidance of the instructor.

Another definition given by Lage at al. (2000) is "*Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa*". Most research on the flipped classroom employs group-based interactive learning activities inside the classroom, citing student-centered learning theories based on the works of Piaget (1967) and Vygotsky (1978). The exact nature of these activities varies widely between studies. Similarly, there is wide variation in what is being assigned as "homework". The flipped classroom label is most often assigned to courses that use activities made up of asynchronous web-based video lectures and closed-ended problems or quizzes.

Bishop (2013) defines the flipped classroom as an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom and rejects designs that do not employ videos as an outside of the classroom activity.

For this task, the students are requested to prepare adequately each Lab session before coming to class, thus avoiding the need to devote classroom time to explain and perform easy examples that can be self-learnt. This methodology aims firstly to increase the motivation and improve the perception of the Mathematics subject by engineering freshmen, helping them to understand the main topics and increasing the interactivity with the lab environment. In this way the students are able to develop a broad range of competences, apart from solving problems and using tools and aids. They establish more concrete relationships between backgrounds studied in lectures and are prepared out of the class with the ability to solve problems. By doing this we avoid dropouts that happens when students are not motivated (Hughes 2012 & Toto 2009). And above all we aspire to achieve a faster and more natural acquisition of the specific mathematical competences that the course provides.

Along the course programme and covering all of the syllabus' topics, there are 27 LP sessions to be executed. They have been divided into three parts:

- Pre-Class: this first part is devoted to prepare the work that students have to do in the lab and it is based on a flipped class methodology. The students take the pre-class part by themselves without the instructor being with them. Thus the instructor must provide the necessary material to support them so that there is no problem in having the work performed autonomously. Additionally, the students may consult their doubts through the UPV educational platform PoliformaT by using either the forum or chatroom capabilities.
- In-Class: The first part of in-class sessions maybe considered a form of collaborative learning (Beck and Chizhik, 2013; Rockwood, 1995a, 1995b) and is developed during the first 30 minutes of each class. This part is devoted to answer questions, examples and exercises that students propose on the specific topics where they have found some difficulty and the instructor should add and explain elements that he/she considers important if they have not appear between the students doubts. The second part of in-class sessions takes place during the last 30 minutes of each class. Several exercises are proposed to students that are to be solved with the use of the computer algebra system Mathematica. These exercises are performed by each student individually in class (with IPs restrictions) and are aimed to provide an insight into the degree of acquisition of competences covered in that topic. While working out these exercises, the instructor assists students and even helps them with adequate guidance.

- Post-Class: At the end of each session the students may know their grades, review their mistakes and consult their loaded fails in order to detect its deficiencies by using the Gradebook and Test & Quizzes' tool from PoliformaT.

Mathematics laboratories are a good source of activities to be assessed and introduced in the assessment process in a contributive way towards the final objective.

3.5.7 Written exams

Written tests are one of the most common and widespread ways to implement assessment processes. The written tests can be scheduled in many different ways but it is usual to schedule two or three times during the course. They usually are part of a summative assessment process.

A system of continuous assessment cannot be based on the implementation of a few written tests and obtain an average grade. We think that should be considered all possible activities that student can execute within the assessment process, grading each of them as elements which contribute in a continuous learning and evaluation timeline. In Chapter 4 we will develop this topic and call *moments of evaluation* (MoE) to each of these activities.

One of the objectives of each MoE is to obtain a measure of the students' knowledge in a controlled environment that guarantees the job authorship.

From the point of view of the basic competences, written tests are similar to assignments or labs depending on the job in written in paper or executed with the use of scientific software. Thus we should assign weights similar to assignments or laboratory practices but taking into account their major index of credibility or reliability, given that its execution take place in a controlled environment. Given the nature of a written exam, the communication competence takes special relevance.

Evaluation is most accurate and equitable when it entails human judgment and dialogue, so that the person tested can ask for clarification of questions and explain his or her answers. Designing tests should involve knowledge use that is forward-looking. We need to view tests as "assessments of enablement" rather than merely judging whether students have learned what was taught, we should "assess knowledge in terms of its constructive use for further learning” (Wiggins, 1998).

3.5.8 eLearning activities

As we will develop in this work, the continuity property of the continuous assessment process will require as many activities as possible to be executed and assessed. On the other hand, the need to adapt the students’ workload to the particular needs of each of them, different activities to different students should be provisioned. In order to avoid an overwhelmed amount of work to the teachers, eLearning activities take a relevant role in this context.

The introduction of specialized computer technologies in education can provide efficient and timely access to learning materials. According to Clark (1983), these technologies are mere vehicles that deliver instruction but themselves do not influence student achievement. Nevertheless, other researchers suggest that learning is influenced more by the content and instructional strategy in the learning materials than by the type of technology used to deliver instruction (Schramm, 1977). It is the instructional strategy and not the technology that influences the quality of learning (Bonk and Reynolds, 1997) however the particular characteristics of computers bring real-life models and simulations to the learner which positively influence their learning (Kozma, 2001). Anyway, the learning materials must be designed properly to engage the learner and improve the learning (Cole, 2000), and online learning should have high authenticity, high interactivity, and high collaboration (Ring and Mathieux, 2002). Carliner (1999) defines online learning as educational material that is presented on a computer whereas Khan (1997) defines online instruction as an innovative approach for delivering instruction to a remote audience, using the Web as the medium, but always the learner and the learning process should be the focus of online learning. Online learning has to be a subset of learning in general (Garrison & Shale, 1990) since an effective learning is learner centered, knowledge centered, assessment centered and community centered (Bransford, Brown, and Cocking, 1999).

One of the aspects that has more interest in our dissertation context is the quality of assessment-centered as it can introduce some automation in the activities evaluation and be a catalyzer for the continuous assessment process. The execution of activities inside an online learning environment does not give qualified support for summative assessments, it is an instrument to formative evaluation that serves to motivate, inform, and provide feedback to both learners and teachers. In this sense, many students are able to provide coherent explanations, generate plans for problem solution, implement solution strategies, and monitor and adjust their activities (Baxter, 1996). Strategies that are designed to provide formative and summative assessment with minimal direct impact on teacher workload are urgently needed.

This is a crucial aspect in our paradigm about continuous assessment model where the evolution in the development of the competences is based on the contributory execution of as many formative activities as possible. And in this context, training tools that individualize learning according to the needs of each particular student is essential.

Broughton, Robinson and Hernandez-Martinez (2012), have addressed some issues on using computer aided-assessment with students. It saves time in compiling, distributing and marking assessments which is particularly advantageous with large student groups and a large question bank is considered a valuable resource and ensures that compiling assessments remains efficient.

Interactivity is a critical component of these computer-aided environments. Interactivity in the context of computer based learning can be described in terms of different dimensions such as control, adaptation and communication (Sims, 1999). All forms of education are essentially interactions between content, students, and teachers (Garrison and Shale, 1990). The interaction is the component of the educational process that occurs when the student transforms the inert information passed to them from another, and constructs it into knowledge with personal application and value. The student-content interaction is the major component of formal education, even in the form of personal study or the reading of textbooks.

From the point of view of the basic competences, eLearning activities are similar to the activities which are the subject of the proper eLearning activity with the nuance due to the use of technical aids to develop the activity. Thus we should assign weights similar to lectures, assignments or laboratory practices but taking into account the use of technologies.

3.5.9 Other activities

There is a large number of diverse activities that the students can execute and that can be evaluated. A relevant matter is known as 'intended learning outcomes' (Otter 1992): what students know, understand or are able to do as a consequence of the set of learning activities and experiences represented by a unit of study.

The relationship between learning outcomes and assessment has been described by Norman Jackson (2000) as: *Module outcomes predict the learning that students will have demonstrated when they have completed the curriculum unit. These learning outcomes relate directly to the assessment methods and criteria used to evaluate performance. Module outcomes are connected to academic standards through explicit assessment criteria and the evidence students provide of learning. Assessment criteria guide students on the quality of work expected in order to achieve the necessary standard and help academic staff to judge the extent to which the outcomes have been achieved.*

Therefore, we consider important to design activities adapted to the different contents of the course and also the assessment procedure associated with them. Also, we consider relevant to include the execution of the activities in the assessment process and not only the results obtained in two or three written tests. And it is also relevant to dispose of activities' collections covering the development of the eight core competencies that will enable us to modular and monitor the development thereof.

Some examples of other types of activities are:

- Multimedia presentations

  It helps to develop the communication skills by presenting their work orally or in mixed-media form, in front of a 'live' audience.
- Home-exams

  In order to gain experience of working on set questions and problems under pressure, but with more time to reflect or to consult notes and other resources.
- Projects

  This is a type of home assignment that has a major content extension meant to learn how to implement, analyze and report on a survey within a subject area or discipline.

- Computer-based self-testing

  In order to get instantly feedback about they have learned and identify gaps and misconceptions in their knowledge.
- Bibliographic databases

  In order to acquire expertise in the use of applications of information and communications technology (ICT) which have become well established today.
- Forums or blogs

  In order to develop skills in debate and personal communication.
- Peer-feedback

  In order to learn how to assess and so enhance their capacity to apply criteria for assessment. Also to judge the quality of their and others' work giving constructive feedback.
- Group problem solving

  In order to learn about working collaboratively and cooperatively, while also gaining insights into how others tackle questions, define problems or communicate ideas.

Finally, the involvement of the eight core competencies in the execution of activities depends on the content and orientation of the activity. Thus, for example, an activity to develop off the classroom consisting in demonstrating theoretical issues has a greater impact on M11 (thinking mathematically) and M12 (reasoning mathematically) while an activity which consists in solving repetitive problems, as the calculation of function antiderivatives, has a greater impact on M13 (posing and solving problems).

In the word of Biggs (2003), *in aligned teaching, there is maximum consistency throughout the system. The curriculum is stated in the form of clear objectives, which state the level of understanding required rather than simply a list of topics to be covered. The teaching methods are chosen that are likely to realize those objectives; you get students to do the things that the objectives nominate. Finally, the assessment tasks address the objectives, so that you can test to see if the students have learned what the objectives state they should be learning. All components in the system address the same agenda and support each other*.

Therefore, in the design of a course curriculum it is very important to have a widespread catalog of activities collections with their measured impact on the core competencies. Then, the execution of activities can be implemented in a systematic way in the process of continuous assessment. Each activity's execution can be evaluated and get an additive contribution to fuel the continuous assessment process. The more activities are implemented and assessed the closer we will have a model of real continuous assessment.

This catalog of activities is the first step towards a model of individualized learning since different activities collections can be assigned to the students according to their grade of objective achievement individually measured.

As an approximation, a possible table of types of activities and a range of their impact on the development of the core competencies is described in the following table where impacts are classified as High (H), Medium (M) and Low (L):

	M11	**M12**	**M13**	**M14**	**M21**	**M22**	**M23**	**M24**
Lectures	H	H	L	L	M	H	H	M
Assignments	M	M	H	M	M	M	M	L
Laboratories	L	L	L	M	M	M	H	H
Written exams	M	M	M	L	M	M	H	L
Multimedia presentations	L	L	L	L	M	M	H	L
Home exams	M	M	M	L	M	M	L	L
Projects	H	H	M	M	M	M	H	L
Computer self-testing	M	M	L	L	M	M	L	L
Bibliographic databases	L	L	L	L	L	L	L	H
Forums and blogs	M	M	L	L	L	L	H	M
Peer-feedback	M	M	M	L	M	M	H	L
Group problem solving	H	H	H	M	M	H	H	L

In the next chapter, we introduce a model of continuous assessment based on the execution of activities and their impact on the core competencies.

4 A procedure to compute continuous assessment

4.1 Introduction

Assessing competencies is always a difficult issue, particularly in the first year of university engineering degrees when students with different backgrounds are learning together. In fact, this issue is tackled in SEFI Mathematics Working Group (2013, p 68), where we find that assessing and grading are extremely important parts of the teacher's work. The grade achieved by a student, in relation to what other students have achieved, can determine his/her future, the first job or a PhD education for instance. The students know this and find it in general extremely annoying – it may even have a strong negative impact on the interest in the subject – if the assessment is considered unfair.

Assessment methods based only on traditional written exams may fail to guarantee that all the competencies required in a programme of studies have been achieved, mainly due to time constrains. When other competencies rather than skills and knowledge are added, the assessment method must include more types of activities and the assessment has to take into account a complete observation of the learning process.

As mentioned in Chapter 2, different learning theories have been developed which determine the use of different assessment methods. In traditional philosophy, the learning was teacher-centered and the assessment based on mastery of concepts.

Contemporary progressivism involves informal and participatory assessment (Kapambwe, 2009).

Continuous assessment is the most accurate method in order to evaluate a student grade and must include several kinds of activities and tests along. It makes use of assessment procedures which contribute to the development of understanding versus the acquisition of concepts. It is formative and summative, focusing on individual's progress in learning and on assessment of the learning outcomes.

Despite the continuous assessment term, grading is a discreet process that comes from pictures taken through moments of evaluation carried out by means of activities, lab classes, exams, ... A continuous assessment should reflect the effort developed by the student in due time as well as the competencies shown at each moment of the topic under study and, not to be dismissed, the competencies whose specific moments of evaluations have already been done in the past (Mínguez and Sánchez Ruiz, 2014).

In this chapter we present and discuss a new approach based on the *integration of different sets of activities*, the measurement of results in a temporal sequence of *moments of evaluation* and an *active/retroactive feedback* component in order to estimate a final grade to complete a continuous assessment process. We focus our approach in Mathematics, but clearly our paradigm in continuous assessment may be applied to any discipline where some chains of topics can be clearly identified.

We raise three questions which we consider relevant and should be taking into account in order to follow a continuous assessment:

Q3: Could we establish an assessment process that runs parallel to the learning process?

Q4: Could the assessment process deal with different students learning needs? (i.e. be inclusive)

Q5: How could the students obtain a right feedback to direct them to achieve the targets?

We will tackle them in this and subsequent chapters.

In particular, our answer to question Q3 comes by implementing an intensive execution of a great variety of activities covering the whole curriculum from the perspective of the competencies.

Question Q4 is a little more complex and it will be discussed in subsequent chapters. We may advance that with a broad spectrum of well classified activities by levels of difficulty and syllabus item oriented, it is possible to build a personalized portfolio of activities that matches up the individual needs of each student.

In order to provide an answer to question Q5 we introduce the concept of active/retroactive feedback to track the competences improvement (active component) and to emerge competence's lacks (retroactive component) and provide the student the way of redeeming them.

Since this dissertation does not deal with methodologies and instruments of evaluation but with establishing a computational algorithm that guarantees the validity of the process of evaluation, we will review some relevant opinion on assessment and continuous assessment procedures that extent the brief introduction on assessment methods given in Chapter 2. We will include timely comments on how they fit within our study about a new paradigm on continuous assessment develop in section 4.3.

4.2 The continuous assessment process

4.2.1 Background

» Accordingly with Terenzini (1989), one of the most significant obstacles is the absence of any consensus on what "assessment" means. We will address his three questions:

- *What is the purpose of the assessment? The answer to this question parallels the purposes of formative and summative evaluation: the first is intended to guide program modification and improvement, while the second is undertaken to inform some final judgment about worth or value*.

  We agree with this statement. In fact, including a lot of different and well-designed activities covering the whole curriculum makes the evaluation formative. Students get formative assessment and feedback executing activities oriented to develop the basic competences. A right progression of the activities content taking into account their interrelationships establishes a summative assessment process as well.

- *What is to be the level of assessment? Who is to be assessed? Will the assessment focus on individual students, where the information gathered on each student is inherently interesting? Or will it focus on groups, where individual information is aggregated to summarize some characteristics of the group?*
  Implementing a continuous assessment process as continuous as possible implies the students are assessed in each and every one of the aspects of the formative progression. The assessment is student-centered and focuses on their individual needs since a personal activities portfolio could be define in order to deal with their uniqueness. On the other hand, aggregating information from individuals enables to construct continuous key performance indicator (KPIs) to characterize the entire group or may be used to cluster subgroups in order to assist different training needs.

- *What is to be assessed? For example, a simple yet useful general typology has been given by Ewell (1984) who suggests four basic dimensions: knowledge outcomes, skills outcomes, attitudes and values outcomes, and behavioral outcomes.*
  The four basic Ewell's dimensions can be observed when of the activities are designed for these purposes. Notice that controlling the execution of a long activities stream also serves to register behavioral outcomes and get them back into line if necessary.

» Following Brown (2004) they argue that assessment needs to be 'fit-for-purpose'; that is, it should enable evaluation of the extent to which learners have learned and the extent to which they can demonstrate that learning (Brown and Smith, 1997). We find that these arguments are in line with our model of continuous assessment exposed in section 4.3.

- *Our different reasons to motivate students, to encourage activity, to provide guidance and feedback for remediation, grading and selection will impact on our choice of assessment instruments.*

  We propose the evaluation through the execution of a wide set of disparate activities rather than traditional exams and reports for example, which are included in the assessment methodology.

- *We also need to consider when the best time to assess is. Is it possible to give students a choice about when they are ready to be assessed? How far can we (or should we) allow multiple attempts at assessment over a period of time? Why not much longer? Or shorter?*

  Our proposal aims to do as many different evaluations as possible in order to get a high grade of continuity in the assessment process and include the evaluation in the learning process as a valuable task. Then students should feel that they are ready to be assessed because of the results of their previous assess activities.

- *To ensure that assessment is part of the learning process, I would argue that it should be learner-centred assessment and should reflect a learner-centred curriculum. Assessment methods and approaches need to be focused on evidence of achievement rather than the ability to regurgitate information*.

  As we have aforementioned, the inclusion of a great curriculum-covered variety of activities in the process assessment supports this argument. Beyond, students are requested to work on as many activities as they need in order to achieve their target objectives.

- *Any assessment strategy needs to be efficient in terms of staff time, cost-effective for the organizations concerned and should ensure that learners find the tasks they are set manageable, relevant and developmental. We cannot simply expect our students or ourselves to just keep working harder and harder; where possible we must make best use of the available technologies to make assessment more efficient* (Brown et al., 1994).

As it will be developed later, a good media of assessment process support would be a large database of activities containing educational items covering the whole curriculum of a subject from the point of view of training as well as for evaluation purposes. Obviously, this sort of developments involves a great deal of joint effort for educators and educational organizations concerned. This kind of media will help the learning and assessment process to be more cost-effective creating and it will provide self-learning and self-assessment service for students. Additionally, it is a tool that enables to recognize and award improving previous competencies in the chain of topics or propose reinforcement activities.

- *Any assessment strategy that aims to be inclusive should deploy a variety of methods for assessment so that the same students are not always disadvantaged. All participants need to be provided with equivalent opportunities to demonstrate their abilities and maximize their potential.*
  Including a great variety of activities in assessment will enable to generate greater equality enhancing individual skills and giving each student the quantity of necessary effort to reach his/her objectives.

- *The programme of assessment chosen needs to be reliable, so that different assessors derive the same grade for similar work (inter-assessor reliability) and individual assessors mark reliably to a defined standard (intra-assessor reliability). This can only be assured when the criteria are clearly understood by all who undertake assessment.*
  Each activity in the learning database should include the right evaluation criteria.

» The importance of the continuous execution of evaluated activities is to parallelize the assessment with the learning in all its extension and does not limit the certification of the acquired knowledge to a few items expected in a timely review.

- Gibbs (1992) states that *assessment systems dominate what students are oriented towards in their learning. Even where lecturers say that they want students to be creative and thoughtful, students often recognize that what is really necessary, or at least what is sufficient, is to memorize. A*nd citing Biggs

(2002) that *the teaching methods used and the assessment tasks are aligned to the learning activities assumed in the intended outcomes*.

Following Gibbs, we could identify clearly the learning outcomes and design the appropriate assessment tasks (activities) that will directly assess whether each of the learning outcomes has been met and ensure that all the subject items will have been assessed for any student successfully completing the course programme.

Gibbs and Simpson, 2004, *discuss how assessment arrangements can promote student learning. They propose a framework of ten 'conditions under which assessment supports learning', to enable staff to assess and evaluate their own practice:*

- *Sufficient assessed tasks are provided for students to capture sufficient study time.*
- *These tasks are engaged with by students, orienting them to allocate appropriate amounts of time and effort to the most important aspects of the course.*
- *Tackling the assessed task engages students in productive learning activity of an appropriate kind.*
- *Sufficient feedback is provided, both often enough and in enough detail.*
- *The feedback focuses on students' performance, on their learning and on actions under the students' control, rather than on the students themselves and on their characteristics.*
- *The feedback is timely in that it is received by students while it still matters to them and in time for them to pay attention to further learning or receive further assistance.*
- *Feedback is appropriate to the purpose of the assignment and to its criteria for success.*
- *Feedback is appropriate, in relation to students' understanding of what they are supposed to be doing.*
- *Feedback is received and attended to.*
- *Feedback is acted upon by the student*.

This study outcomes the relevance of assessment based on assessment arrangements and the appropriate stream of feedback given to teachers and learners. Again, an evaluation based on execution of assessed activities with immediate return of feedback seems to be a good procedure to parallel assessment to formative process.

» Formative assessment could be seen as formal or informal depending on whether it takes place with reference to a specific curricular assessment framework or it takes place in the course of events which are not specifically stipulated in the curriculum design. Another distinction (Bloom, 1971) is typically made between formative and summative assessment, the latter being concerned with determining the extent to which a student has achieved curricular objectives. Some assessments are deliberately designed to be simultaneously formative and summative – formative because the student is expected to learn from whatever feedback is provided, and summative because the grade awarded contributes to the overall grade at the end of the study unit. Summative assessments in relation to a curricular component can act formatively if the student learns from them. Also feedback is sometimes received too late for student education and may also be insufficient, if only given as a mark or grade, for learning on subsequent modules. The design of activities for assessment purposes has to combine both formative and summative aspects to accomplish with the grading task and objectives. As we will expose later, activities should have different relevancies on the assessment process and some of them will include topics covered in previous ones in a right progression in order to summarize assessment.

In this sense, we include in the evaluation procedure different types of activities, both with a formative and summative intention. The daily training activities are formative activities which produce immediate feedback. After a series of formative activities, we include summative activities with greater relevance weight which become the moments of evaluation as summary of all the formative activity in a given period of time.

» According to Coll et al. (2007), assessment is an element in the process of teaching and learning and is an instrument at disposal of this process. The activities used for identifying and assessing what students have learned constitute the nexus between the teaching process laid out by the teacher and the knowledge construction processes by student. And the assessment activities must be coherent with the other elements which make the teaching and learning process up, especially with objectives and with activities throughout this process. Coll et al. argue that teaching and learning activities are at the same time assessment activities and they are designed into thematic blocks which connect one or more topics. Each block proposes a set of continuous assessment activities which require the students to produce different products in a complex case analysis or problem-solving situation. At the same time, continuous assessment activities are planned in such a way as to facilitate the teacher's follow-up of the students' work progress, by producing written reports to be returned to students and by performing follow-up tutorials based on assessment results from each thematic block.

In this sense, we propose the evaluation of execution of activities as a parallel process to the learning process so that the students can obtain a continuous feedback about their learning progression. As we will see later, the introduction of *retroactive negative/positive* component produces a stream of continuous feedback about the status of knowledge on the different topics within a subject.

» Some recommendations about when to assess and how to assess knowledge, skills and competences have been given by Hoffmann (2011a):

- *If the learnt information will not be used during the first weeks of the new lecture period, there is a considerable probability that good parts of it will be forgotten, though the examination might have resulted in good marks. Careful adjustment of appointed times for assessment and of arrangements for appropriate usage of learnt information is thus necessary*.

  We agree with this proposition due to we do no propose a methodology about assessment but a procedure to compute a reliable grade as result of assessment process. In this sense, sets of activities could be timely planned in order to establish and appropriate sequence of remembrances.
- *The width of learning material for knowledge and skills to be tested must be defined in carefully prepared descriptions of curricula modules, including a set of factual, conceptual, episodic, procedural, and canonical knowledge that are required to be outcomes of the learning process*

  Again, an execution of different types of activities are proposed.
- And clearly, competences are difficult to assess out of a concrete context. We are treating in this dissertation with mathematical competences as a very particular

type of competences which could be more feasible to reproduce the adequate context in with they could be assessed. In this sense, a bit more complex activities from the point of view of their execution can also be proposed and fueled into the assessment procedure.

» Other authors like Birenbaum (2006) states that assessment for learning addresses individual learners' needs by focusing on formative assessment providing learners with information about their progression. Integrated Assessment Systems (IAS) would be beneficial to both learners and teachers. The implementation of Integrated Assessment Systems would allow teachers to spend time focusing on developing the teaching of the curriculum instead of teaching to pass the test; spend less time with the preparation and/or administration of assessment and get useful information about individual learners' progress from Integrated Assessment Systems, i.e. through formative assessment modes. On the other hand, IAS would allow learners to test themselves both independently and/or under the teacher guidance when appropriate as a means to review progression; the implementation and use of IAS would be less and less viewed as 'tests' and gradually become part of a 'task set' and the implementation of IAS would allow learners to get information about their individual learning progression, i.e. allow for formative self- assessment.

4.2.2 Features from the KOM project

In this work we focus on the process of evaluation of mathematical competences although as mentioned above it is possible to extrapolate to another disciplines.

Thus, we propose developing the assessment process based on a collection of disparate activities in line with the KOM project (Niss M. 2003), and the identification of *chains of topics* as well as a feedback method aimed at estimating the learner's grade of knowledge as close as possible to a continuous model by ensuring that assessment's tasks are feasible in time and effort, too.

According to Niss (2003, Chapter 9), competencies are manifested in activities, having in mind that:

- A mathematical activity consists of a set of conscious and goal oriented mathematical actions in a situation. It could be to solve a pure or applied mathematical problem, to understand or construct a concrete mathematical model, to read a mathematical text with the view of understanding or acting on it, to prove a mathematical theorem, to study the interrelations of a theory, to write a mathematical text for others to read, or to give a presentation.

- Carrying out any mathematical activity demands the exercise of one or more mathematical competency. It is really important to define and characterize the activity and its component parts and demands in a relatively well-demarcated and clear way. A study of which competencies a person actually brings into play in a given activity is above all an empirical enterprise. It can only be realized if the content of the competency in a person's actions while carrying out the activity and the results of such actions are detectable in a valid, reliable and clear way
- Different activities will hereby also provide opportunity for the involvement of different sets of competencies. It is to be expected that for one to achieve a comprehensive and rich picture of a person's mathematical competencies, one must study that person's actions within a broad range of mathematical activities.

Since the competences are expressed via mathematical activities then we need to find a set of activities which together establish a reliable procedure to measure the total mathematical competence profile of each student. In this sense, the KOM project introduces the three dimensions: degree of coverage, radius of action and technical level as a keystone in the description of the progression of a person's competency mastery. Degree of coverage is a measure of the extension we master the aspects which characterize a competence, radius of action is the context where a person can activate the competency, and technical level is referred to the conceptual entities and tools which are relevant with the competence. The three dimensions are expanded over time and are not equally developed in all students.

One of the most important tasks of the KOM project has been to investigate the possibilities of identifying, characterizing and judging progression in a student's development of mathematical competencies as he or she progresses through the education system. A way to measure this progression might consist in discovering the relationships between the collections of activities drawing a set of directed paths in which the learners are developing their skills. This method is compatible with the observation of the competence’s degree of coverage, radius of action and technical level expansion over time because of the sequence of activities is set in a progression which promotes that such expansion can take place.

One of the most important tasks in KOM project consists in creating a procedure to judge the progression in student’s development of mathematical competencies as he/she advances through the education system. Execution of activities can improve one or more of the three key dimensions. For this reason it is important to design collections of activities so that they cover the desired grade of improvement of the three dimensions and the desired level of achievement of the target competencies. Consequently it is important to execute the set of activities in the right order to guarantee a continuous improvement of the three aforementioned dimensions. That justifies the relevance of setting directed paths or **chains of topics** as we have called them. In this sense, the set of topics of any given subject is a partially ordered set (or poset) if we write that topic T1 <= T2 when the content of T1 precedes and are used to understand the contents of topic T2. Let us recall that a chain is a totally ordered subset of a partially ordered set. We will eventually represent as T1 -> ... -> Tn to a given topics chain T1<= ...<= Tn.

Chain of topics has a connection with the concept of learning path used in the literature (Clement, 2000; Jih, 1996). While learning path is a concept closer to the consecution of a knowledge objective through the choice of different types of activities that may converge to this goal, chain of topics is a more appropriate term to represent the precedence within the different topics covered in a course programme. The topics need to be arranged in sequences that enable the student an orderly understanding of the concepts given that a course has a great variety of concepts and techniques to be developed.

4.3 Active/retroactive continuous assessment process

Taking into account the continuous nature of the learning process, the assessment process should also be of a continuous nature. It should be similar to the acquisition process, i.e. by means of the activities execution, only that concentrated in a short space of time and in a controlled and verifiable context.

The assessment process activities are to be defined and should be representative of the competence to be measured: Its successful execution means a certification of the acquisition of the level required to conclude that the competence has been acquired.

The competences are achieved by means of execution of activities. If we assume that the continuous assessment process may be embedded by the continuous acquisition of competences, we could establish that the execution of a number of activities generates a succession of the states approaching to the level of required competence.

Therefore, the execution of an activity should be successful in order to increase the level of competence and, consequently, it is necessary to define or to "measure" when an execution is successful. In general, the level of competence acquired should be considered as an estimate when we do not fully control the execution context of the activity (the student is at his/her home, in the campus, it might be executed by other student, etc). In fact, a major blockade is to guarantee the identity of the student who carries out online activities (Qinghai, 2012). This is the first step if we are to transfer many of the academic activities from the classroom to the universities educational platforms and networks. We should try to increase the guarantee of the identity of the students running activities online as much as possible (Eplion, 2009; and Cabrera, 2013).

The evaluation process is basically the same, i.e., the execution of a set of activities but in a controlled context. In this case we get a more reliable measure instead of an estimate. But there is an additional important difference. In the acquisition process, the execution of activities contributes to increase the value of the unitary competence. Through the evaluation activities the goal is to measure the level of competences achieved even though eventually they can also contribute to increase the level of competence.

We execute the evaluation process throughout a discreet number of measurement points called **moments of evaluation (MoE)**. Every moment of evaluation has a previous domain defined by the set of activities necessary for the development of the process (units of study, classes, practices, group work, etc…) associated with a specific profile.

Time is continuous and the learning process could be viewed of continuous nature by means of a sequence of training activities. We are always learning by means of adding information items to our intellectual background across a continuous set of experiences attending lectures, studying, reading, making reports, socializing, etc… Therefore, a pure continuous assessment model would mean that every activity within the curriculum development should be evaluated and generate the corresponding feedback for students and teachers so that both could shape the formative process and cast the achievement of their targets. This is really utopian in terms of effort and cost. Regardless of the cost, a large number of activities can be included in the process assessment and be evaluated by very diverse methods like peer-assessment, self-assessment, working groups, computer aided programs, etc… in addition to the teacher. As we have aforementioned, the main evaluation activity needs a discretization of the time into moments of evaluation. The more frequent the moments of evaluation are the more continuous the evaluation is. In consequence, we will classify the activities into two primary categories according to their nature formative and summative; and the main moments of evaluation will be implemented by means of the execution of summative activities. Additionally, the remaining activities will be included in the assessment process all of them contributing to the achievement of the final grade. The more activities are included in the evaluation process the more continuous the evaluation is and more parallel to the learning process and, in essence, more formative. Beyond, we could consider any execution of activity as a moment of evaluation.

Actually, at the end of a course the students are given a final grade to certificate their performance along the course. Each activity is formed by an evaluation instrument and an evaluation procedure whereby the activity is marked with a grade.

Let us establish a function g_a called “grade obtained by” which assigns a punctuation $g_a(A)$ to activity A execution through an evaluation procedure in a given moment of evaluation.

Let $S = \{A_i, i=1,...,n_S\}$ be a set of activities. We define the grade obtained by *S*, *g*(S), as

$$g(S) = \frac{\sum_{i=1}^{n_S} w_i g_a(A_i)}{\sum_{i=1}^{n_S} w_i},$$

where each w_i is the weight representing the relevance of the corresponding activity A_i.

Indeed we might consider a moment of evaluation (MoE) as a set of summative activities MoE = {M_i, i=1,...,n_M} used to fix a student grade at some given instant of time T for a specific topic or set of topics.

In our assessment model, the principle is that all the activities are assessed. But we distinguish between training activities and evaluation activities. Training activities refer to the activities executed with the objective to learn and practice the topics covered in the course. Evaluation activities refer to those activities used to fix an intermediate and contributive grade for one or more topics. Evaluation activities are the equivalent to traditional partial or final exams. In order to manage both types of activities, all of them are assessed but training activities have a very smaller weight than evaluation activities.

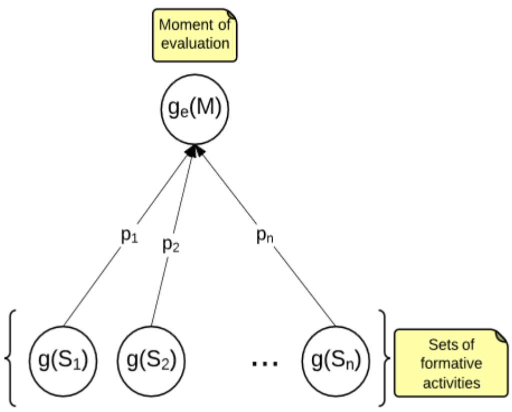


Fig 4.1

Then, a MoE could be considered as a set of summative activities, the evaluation activity, and several sets of training activities whose execution are previous to the evaluation set.

Figure 4.1 represents a collection of set of formative activities S_i and a summative set of activities M which represent the concept of MoE.

Before the execution of the MoE, the execution of the formative sets of activities contribute with a weight p_i to the summative set M, so that we could estimate a grade $g_e(M)$ as an immediate feedback to the student. If the students obtain estimations below a given threshold grade, they would be able to execute more activities of the same nature to improve their outcomes until they get a successful estimation.

The estimated grade g_e is defined only for feedback purposes and it is desirable the existence of a technical platform through which to be able to evaluate or, at least, to introduce the grades of each activity in order to estimate it. By this reason, we have not implemented this feature in our actual studio with a sample of students which is described in Chapter 7.

Once the MoE M has been executed, the estimated grade shall be replaced by the execution grade. It would also be interesting that a percentage of the estimate grade might have some impact on the execution grade. This feature could be seen as a contribution of the training work done by the students and it is a relevant aspect of the motivation aim of the model.

Pursuing the idea that the discreet assessment process can be considered representative of the continuous process of acquisition, we will build an "**active/retroactive continuous assessment model**" up based on the existing partial order relationships among specific curricular domains and the 'moments of evaluation'. In this sense it attempts, at every moment of assessment, to reassess the level of previous skills (scope, maintenance or degradation).

In a pure model of continuous assessment, each session of evaluation should assess the competences achieved at that very moment and earlier. As this alternative is not feasible because of time limitations, we propose an approach based on the fact that the acquisition of a competence is based on the acquisition of previous competences owing to the recursive and accumulative nature of the general learning process.

On the other hand, a failed evaluation of a competence implies a lack of level in that competence and, quite likely, a bad acquisition of previous competencies, a degradation of its level or a failure in the measurement process.

The competencies to be evaluated have got a natural partial order so that they may be represented by means of a graph. We will consider each node of this graph to represent a moment of the evaluation of competencies.

Let us draw the aforementioned graph as a directed graph where the measurement of evaluation of every node has three sets of arches:

- An incoming arch which represents the contribution of the evaluation of the specific competence to be assessed in that moment of evaluation to the general grade.
- A set of outgoing arches towards the predecessors' competences related to the competences evaluated at that moment of evaluation. They represent a

component of retroactivity toward previous assessments with a positive or negative contribution depending on the success of the moment of evaluation.

- A set of incoming arches representing the contribution of specific activities to be taken into account in the evaluation process.

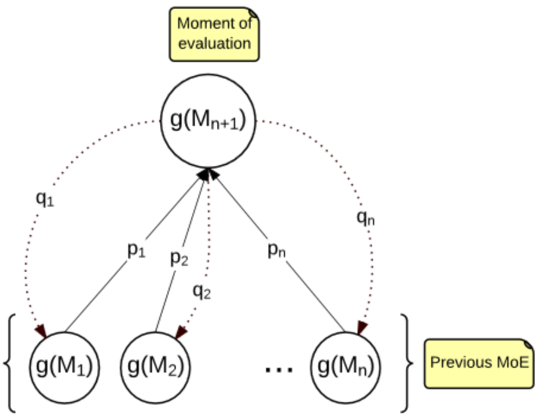


Fig. 4.2

Figure 4.2 represents a precedence graph between different MoEs. Likewise in the figure 4.1, the executions of the MoEs $\{M_1, ..., M_n\}$ contribute with weights p_i to estimate the grade $g_e(M_{n+1})$ which are deactivated when the moment M_{n+1} is executed and changed by $g(M_{n+1})$. And it also serves as an estimation procedure regardless of whether a percentage of MoEs execution could be reserved as a contribution to M_{n+1}.

After the execution of M_{n+1}, the weights q_i applied which represent the retroactive component that could have positive or negative effect over the preceding MoEs $\{M_1, ..., M_n\}$.

In order to clarify the second item above, we may think in some specific example, *e.g.* not to overcome adequately the evaluation of calculus of surfaces of revolution may be due to a poor ability in the process of calculation of antiderivatives and not to a deficiency in the approach to the calculation of surfaces of revolution itself.

This failure should be identified in the process of evaluation (to know where exactly the lack is) and propagate descending arches toward the predecessor's competences and even correct downward the levels previously measured as acquired.

Conversely, to overcome successfully the calculus of surface of revolution may imply a good ability in the resolution of antiderivatives, thus indicating that the level of that competence had effectively been achieved or has improved. In this case, the graph propagates a null or positive contribution toward the predecessor's competences correcting accordingly the level previously acquired.

Summarizing, the retroactive component has two possible implications:

- A failed evaluation of a competence could mean a lack or degradation in one or more previous competences. Then, the model might introduce a downward impact on the outcome assessment of the concerned competencies evaluated in that very topic's chain. This can be hosted poorly by students, but the model is to be built with the aim of measuring the level of competences achieved and maintained throughout the course. Under this situation, we must establish a redeeming plan requiring the execution of concrete reinforcement sets of activities.
- Fig. 4.3 represents a failed evaluation of moment M where the retroactive component transforms the activity A_2 from medium status into a failed status and the activity A_n from a success status into a medium status.

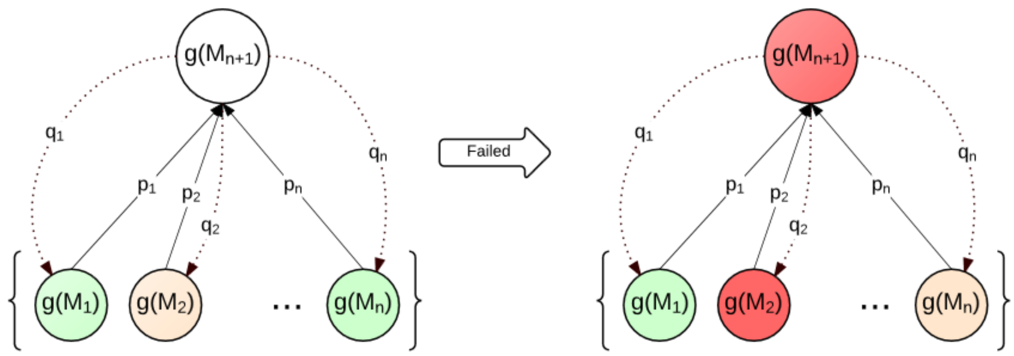


Fig. 4.3

- A successful evaluation of a competence could be considered as a sensible indicator that some previous lack has been overrun and, in this case, we could apply an upward retroactive impact on the outcome assessment of one or more previous competences.

Fig 4.4 represents a success evaluation of moment M where the retroactive component redeems A_2 from medium to success status.

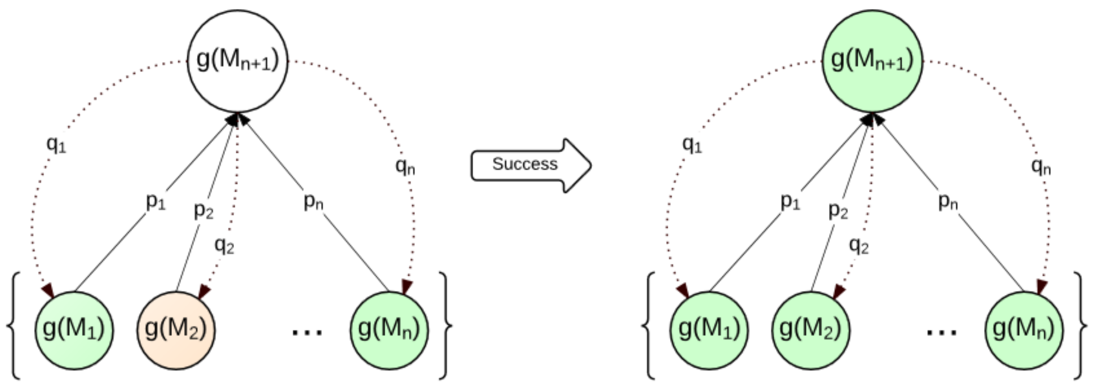


Fig. 4.4

On the other hand, the active component has a more delicate implementation. Although a successful execution of a moment of evaluation could be interpreted as an indicator of future success in one or more evaluations on the same topic's chain, it does not seem a good strategy awarding credit scores to be added to future evaluations. However this is indeed carried out when the execution of activities is taken into account in the final grade.

A final grade is obtained when the student reaches a competence threshold in all and each of the competences defined in the course programme. In this sense, the active/retroactive component introduced in the model aims to identify those competences that have and those that have not been adequately achieved. It is a tool that eventually may enable to recognize and award improving previous competencies located in the topic's chain path under consideration or propose reinforcement activities to achieve the course objectives in an individualized manner.

Distinct algorithms can be designed in order to compute different strategies to assign a final grade.

4.4 A case: continuous assessment of Mathematics I at ETSID

Let us now provide an example on how this continuous assessment method has been used in a Mathematics subject, namely Mathematics I of BEng Aerospace Engineering at the School of Design Engineering in Valencia ETSID (Universitat Politècnica de València UPV, Spain). The material covered in this subject keeps its outreach at Level 1 as referenced in SEFI Mathematics Working Group (2013, pp 29-36), (Mínguez and Sánchez Ruiz 2014), (Mínguez, Moraño, Roselló and Sánchez Ruiz, 2014), (Mínguez, Moll, Moraño, Roselló and Sánchez Ruiz, 2014), in most of the topics. However, Aeronautical Engineering being a quite demanding mathematical discipline requires some Level 2 topics covered in order to achieve the appropriate background to address other subjects of the BEng programme. No Level 3 is considered since this is designed for a first year student course and there are other subjects in the forthcoming courses which deal with more advanced mathematical concepts.

Hence, the student needs the competencies provided by this mathematics subject to acquire basic skills for the resolution of the mathematical problems that arise in Engineering and its ability to apply knowledge about linear algebra, geometry, differential geometry, differential and integral calculus; and an introduction to differential equations and numerical methods that are thereafter completed in Mathematics II and Mathematics III respectively (Universitat Politècnica de València a).

The corresponding specific competencies of these topics are achieved through the execution of different types of activities:

- Theory and Problem solving throughout attending on site classroom lectures.
- Laboratory Sessions as well as their corresponding exams by using the computer algebraic system Mathematica (Moraño and Sánchez Ruiz, 2012) and the UPV educational platform PoliformaT (Universitat Politècnica de València b).
- Answering Quiz tests at the end of theoretical classes or lab sessions.
- Answering on site class tests based on homework activities

- Written exercises some of which involve more comprehensive and complex practical questions which occasionally are done online with partial self-assessment (Sánchez Ruiz and Moraño, 2010)

We distinguish four blocks of competencies to be achieved within this subject with the following distribution:

- Calculus I (C1), dedicated to the study of real functions of one variable, derivatives, integration and their applications so that the students should be able to:
    - Work with the derivative of a function of one variable. Inverse functions. Exponential, logarithmic, and trigonometric functions. Hyperbolic functions and their inverses.
    - Operate properly with complex numbers in various representations. Find exponential and complex logarithms.
    - Define the roots of equations and find them by numerical methods.
    - Graph functions in cartesian, parametric and polar coordinates.
    - Know the basic results about the integration of functions of one variable.
    - Calculate areas of surfaces of revolution, some volumes of solids and lengths of curves as applications of the integral.
    - Solve basic ordinary differential equations and apply them to model and solve some physical and geometric problems.
    - Approximate integrals using trapezoidal and Simpson rules. Know the basics about improper integrals; in particular, the convergence criteria and their application in specific cases.

- Linear Algebra (A) which contains material oriented to matrix calculus and resolution of linear system and matrix diagonalization so that the students should be able to:
    - Take advantage of the properties of the matrix calculation to solve systems of linear equations.

- Study vector spaces and subspaces. Find basis, dimensions and coordinate systems.
- Calculate determinants and apply them to concepts related to the structure of a vector space.
- Compute scalar product, distances and angles and apply them to least squares method.
- Find the eigenvalues, eigenvectors and characteristic equation of a matrix. Diagonalize an endomorphism when possible.

- Calculus II (C2) including the study real functions with two or more variables, partial derivatives, multiple integral and their applications so that the students should be able to:
  - Interpret the functions of two variables as a surface and the meaning of the partial derivatives.
  - Calculate partial derivatives of a function of several variables; apply the chain rule.
  - Understand and apply the implicit function theorem.
  - Find and recognize equations of elementary surfaces such as cylindrical and revolution surfaces
  - Find tangent planes and normal lines to surfaces and tangent vectors to curves.
  - Calculate double and triple integrals in Cartesian coordinates as well as by making use of adequate change of variables; in particular, in polar, cylindrical and spherical coordinates.
  - Calculate line and surface integrals and its applications
  - Recognize conservative fields when evaluating line integrals.
  - Apply the classical theorems of vector calculus: Green, Stokes and Divergence.
  - Calculate in the adequate setting a work, length, area, volume, mass, average, center of gravity, moment of inertia and flux integrals.

- Series (S) introducing numerical, power and Fourier series so that the students should be able to:
  - Study the convergence of numerical series and its sum in some convergent cases.
  - Handle power series properly including properties of derivation and integrals.
  - Find Fourier series of periodic functions and functions defined in a finite interval. Interpret the expansions in the extreme points in the case of finite intervals and at continuity/discontinuity points.

The methodology followed during the course corresponds to blended learning (b-learning) since a set of very different techniques are followed as described above to which we may add flipped learning and cooperative learning as lab sessions are developed as follows: the students are requested to prepare each lab session before class, for which they are provided with adequate material, bibliography and textbooks (Sánchez Ruiz and Legua Fernández, 2008; Legua Fernández, Moraño Fernández and Sanchez Ruiz, 2010; Moraño Fernández and Sánchez Ruiz, 2012). Lab sessions run as explained in section 3.7.5.

These four blocks have got the corresponding “moments of evaluation” to be executed along the academic year and each of them has a different weight in the final grade (FG) that is the mark of the subject. This final grade also takes into account a set of autonomous activities (Act) set to facilitate the learning process. All these form the theoretical/practical knowledge (TP) of the subject.

These moments of evaluation are summative activities inside a whole set of activities which define the work to be assessed within the course programme. Other activities accounted in the assessment process are the laboratory practical classes (LP) which include weekly assessment through individual work at lab sessions and two individual lab exams at the end of each semester: LEx1 covering C1 and LEx2 covering A, C2 and C3 respectively, where C3 is composed of C1, C2 and S in order to pursue a more accurate continuous assessment of the level of competencies achieved.

Thus, we have six different main moments of evaluation corresponding to C1, LEx1, A, C2, C3 and LEx2, and we identify the following chains of topics:

- C1 → LEx1 → LEx2
- C1 → C2 → C3 → LEx2
- A → C3 → LEx2

TP assessment is implemented with a weight of 75% in the final grade (FG) which is a measure of the level achieved of the whole set of competencies to be evaluated across written exams covering C1, A, C2 and C3 blocks.

Lab Practice assessment has a weight of 25% in the total FG punctuation. It is obtained through an auto-assessment process executing activities on the e-learning UPV platform PoliformaT and two on site lab exams LEx1 and LEx2. With these elements we may draw a graph representing the moments of evaluation in nodes and the relationship between them with arches. We are also considering the concept of retroactivity in this graph.

In Fig. 4.5 we represent the relationship between the different moments of evaluation listed above in a summarized graph where dotted arches C1->C2, A->C3, C2->C3 represent the partial order existing between different moment of evaluation. For instance the first one refers to the fact that skills developed during C1 learning time are necessary to study and achieve competencies included in C2; whereas at the same time they represent a retroactive contribution between them.

The weights p_1, p_2, p_3 and p_a represent the contribution of the assessed moments C1, C2, C3 and A blocks to the final grade (FG). Additional contributions P_{act} and P_{lab} come from activities and lab practice.

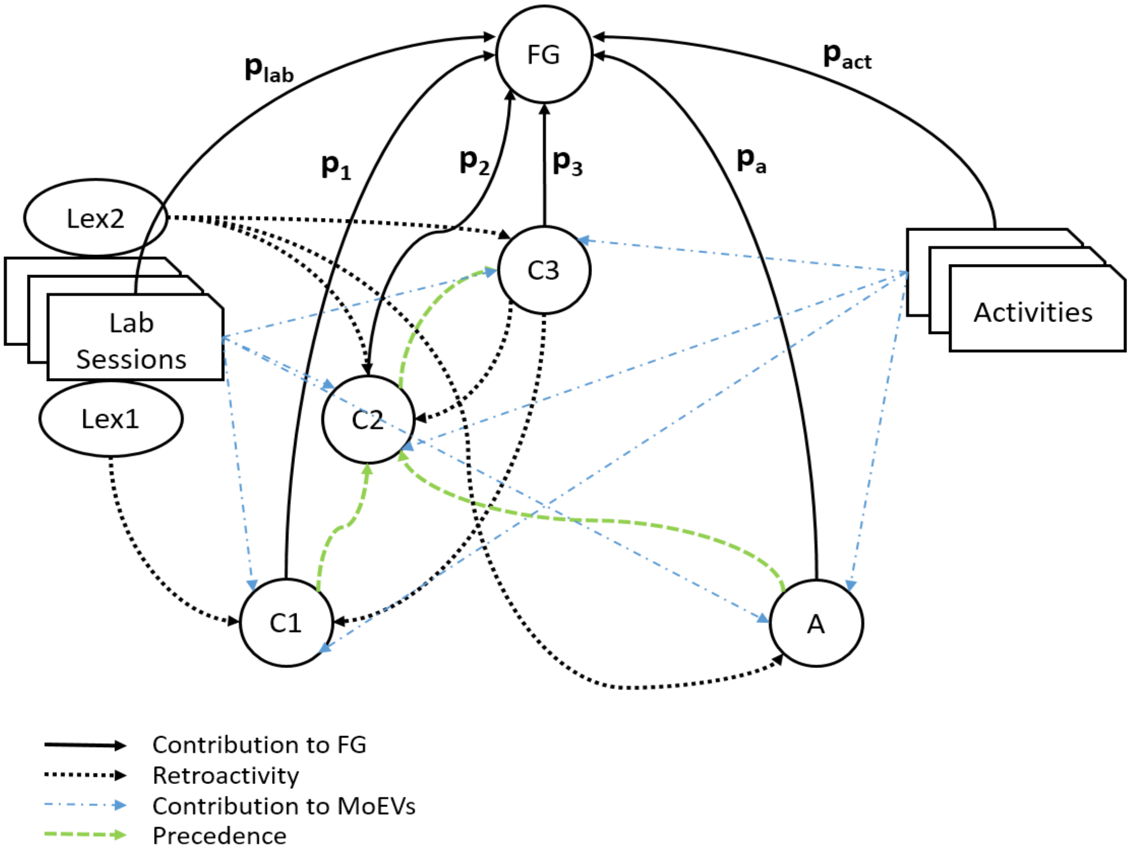


Fig. 4.5: Assessment's graph

The graph only represents the main moments of evaluation and their relationships. These moments are the summative activities which have a major contribution to the final grade. Additionally, the set of activities drawn on the right part of the figure represent a variety of different types of activities executed in parallel to the course which also have been assessed. The dotted arcs represent their contribution to corresponding moments of summative evaluation.

Obviously, there are more relationships between nodes reflected in Fig. 4.5 as the moments represented in the graph are set of competencies and more precedence relationships do exist between their components.

Distinct algorithms can be designed in order to compute different strategies to assign a picture to the final grade FG. We are going to describe the different graph's components and how they contribute to FG according to a retroactive continuous assessment model.

The most important nodes are C1, A, C2, C3 which represent the 90% of the TP punctuation, assignments contributing with the remaining 10%. Each node contains a group of different skills to be achieved in a moment of evaluation which are assessed at the same time. The weights of these nodes during 2013/15 have been set as follows: C1 10%, A 21%, C2 19% and C3 40%. Within C3, the weights are S 40%, C1 30 % and C2 30%. This is done so as historically Aerospace Engineering students perform quite well in Algebra and there is no need to reinforce it through TP. Indeed A is reassess through LP at the end of the course since the moment of evaluation corresponding to A takes place in January, its lab sessions run throughout February and Lex2 takes place in May. The very few students showing some lack in Algebra get a chance to show that they have improved their Algebra competencies by the end of the course in conjunction with C3.

Thus the real final weight of C1 and C2 topics are 22% and 31% at the end of the course within TP which is related to the time dedicated to them and the relevance of its topics.

Summarizing, Table 4.1 shows the distribution of percentages assigned to each moment of evaluation. The “initial” row represents the percentages initially established and the “final” row includes the effect of retroactivity embedded in moment C3.

	C1	A	C2	C3	Activities
Initial	10.00%	21.00%	19.00%	40.00%	10.00%
Final	22.00%	21.00%	31.00%	16.00%	10.00%

Table 4.1: Contribution of ME on Final Grade

Table 4.2 represents the initial and final values of the weights drawn on the graph taking into account that final grade is obtained weighting laboratory practical classes (LP) and theoretical/practical knowledge (TP) with percentages of 25% and 75% respectively.

	p_1	p_a	p_2	p_3	p_{act}	p_{lab}	Total
Initial	7.50%	15.75%	14.25%	30.00%	7.50%	25.00%	100.00%
Final	16.50%	15.75%	23.25%	12.00%	7.50%	25.00%	100.00%

Table 4.2: Contribution weigths of ME to Final Grade

For instance, the successful execution of moment of evaluation C1 should be a goal before executing the moment of evaluation C2 due to the relationships of precedence existing different skills C1 and C2. The ascending arch from C1 into C2 states that C1 competencies are a natural previous requisite to be able to achieve C2 competencies.

Conversely, a failed evaluation in C2 may involve a lack of adequate level in some C1 competencies, a degradation of its level or a failure in the measurement process.

In a real model of continuous assessment, each session of evaluation should assess the previous competencies but this is not feasible because of time limitations. That is why we include some relevant C1 topics within some C2 questions and a retroactive contribution from C2 to C1. Equally with other moments of evaluation across the arches defined in the competencies graph.

A successful C2 evaluation not necessarily implies an improvement of all the C1 competencies in all circumstances. However if there was a lack of C1 achievement competencies while performing C2 it may be considered as a sensible indicator that some lack has been overrun.

For this reason, in our forward/retroactive continuous assessment model the C1 topics included in C2 are to be considered as an opportunity to redeem such situations. When this happens students get their assessment of previously evaluated competencies increased by a percentage of its difference with the newly shown level of competence. This percentage was set as 40% during 2013/15, trying to compromise the newly reached level competence and rewarding when achievements and goals are got at expected due time. In this sense, the retroactive contribution might be considered a reason to introduce positive or negative corrections in previous moments of evaluation's punctuations. At ETSID only positive corrections are applied in previous competencies assessment when the student shows that he/she has reached or improved them in ulterior moments of evaluation. When a failed evaluation occurs, instead of using a negative retroactive contribution when a previously evaluated competence as achieved shows some degradation, we warn them on the precedent related components and propose a set of activities in order to improve the failed skills.

Additionally, lab sessions are assessed in two specific moments of evaluation which represent the 70% of LP through LEx1 covering C1 with a contribution of 28%, and LEx2 covering A, C2 and S with a contribution of the remaining 42%. The other 30% comes from the weekly activities performed in the lab sessions.

Computing algorithms are easily implemented by means of a spreadsheet and we could essay multitude of strategies with different set of weighted arches on the graph in order to maintain a suitable and continuous level of interest in students.

Fig 4.6 gathers the student results following this active/retroactive assessment method since 2013.

Year	Success	Fails	Dropouts
2013-2014	112	4	6
2014-2015	107	6	2

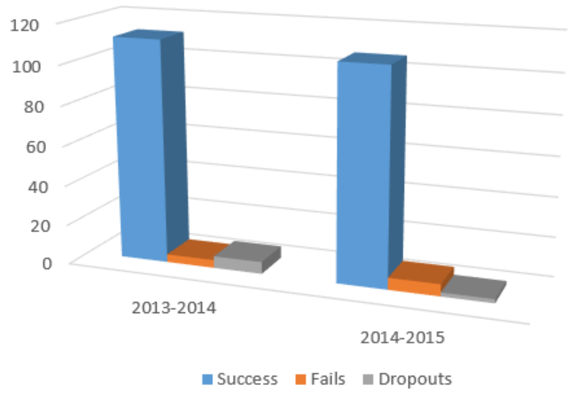


Fig. 4.6: Results of active/retroactive continuous assessment

This assessment practice has proven to be a motivational tool for students. Number of dropouts without final grade has even disappeared some given year (2012-13), and during 2013-14 the number of Fails has been just out 4 of 122, the success rate being circa 92%.

5 The ATC cuboids in assessment of mathematical activities

5.1 Introduction

When applying continuous assessment to mathematics subjects, defined competences should be achieved. The Danish KOM project (Niss and Højgaard, 2011) contains many relevant key points about the mathematical competences that need to be developed by the students of an educational system, and draws a guide to ensure the progression and coherence in mathematics teaching as well as how to measure those mathematical competences. We introduce in this work the implementation of an algorithmic method to compute the overall competences to be achieved by the students through a course programme.

The basis of the study is the eight competences described by KOM project and how they are manifested in activities to be developed within the different topics covered in a syllabus. Each activity is evaluated from the perspective of the eight competences by means of a binary evaluation of each competence based on an assessment by rubrics with a true/false punctuation.

Thus, the base concept refers to the evaluation from the point of view of competences achievement. We include the next question to develop:

Q6: Which way should we assess the execution of activities bearing in mind the achievement of competences?

We put the numerical quantifications of the relationships between Activities, Topics and Competences into a three-dimensional matrix. We will call ATC cuboids to this kind of matrix due to their components. These matrices can be studied from different points of view and important conclusions can be extracted about the internal structure of the student's learning progression.

An ATC reference cuboid designed for a specific course profile serves as a measuring patron and could be a good tool to suggest different strategies for planning work activities as well as a tool to individualize different study needs for different student's situations.

Then, we propose two more questions to study:

Q7: Can the ATC's matrix provide an internal representation of a student's learning progress?

Q8: Could the ATC's matrix be useful to individualize each student's curriculum in order to get his/her individual objectives within a generalized course plan?

We will by recalling the bibliography referring to the evaluation for rubrics in order to introduce the concept of binary assessment. From this idea we will construct the concept of ATC matrix.

5.2 Assessment by rubrics

A rubric is a coherent set of criteria for students' work that includes descriptions of levels of performance quality on the criteria (Brookhart, 2013). The authoress exposes in her book *"How to Create and Use Rubrics for Formative Assessment and Grading"* a complete reflection about the use of rubrics in formative assessment. Rubrics are a descriptive procedure in spite of an evaluative purpose. Of course, rubrics can be used to evaluate, but the operating principle is you match the performance to the description rather than "judge" it. Thus rubrics are as good or bad as the criteria selected and the descriptions of the levels of performance under each. Effective rubrics have appropriate criteria and well-written descriptions of performance. Anyway, the main purpose of rubrics is to assess performances observing the student in the process of doing something or observing the product that is the result of the student's work.

Rubrics give structure to observations describing the performance instead of judging it. Rubrics are usually categorized in analytics or holistic depending on whether criteria is evaluated separately or simultaneously.

Analytic rubrics are appropriate for formative assessment because students can see what aspects of their work need what kind of attention and also for grading that will also be used to make decision about an immediate future. On the other hand, holistic rubrics are appropriate in those situations in which students will not see the results of grading and you will not really use the information for anything except a grade.

One way to support thoughtful self-assessment is to provide a rubric or create one with students. A rubric is a document that lists criteria and describes varying levels of quality, from excellent to poor, for a specific assignment (Andrade, 2000). In addition, self-assessment can be enhanced with peer assessment and teacher feedback.

Airasian and Russell (2008) explain rubrics as “a set of clear expectations or criteria used to help teachers and students focus on what is valued in a subject, topic, or activity”. The criteria are usually descriptive and generate a common understanding of what is valued in a performance. A rubric includes both the aspects and characteristics of a performance that will be assessed and a description of the criteria used to assess each aspect.

Scoring rubrics is typically employed when a judgement of quality is required and may be used to evaluate a broad range of subjects and activities. Judgements concerning the quality of a given work may vary depending on the criteria established to assess and can focus on many different aspects or in a combination of some of them.

In this work, we are going to use rubrics to introduce a method to assess activities based on the development of the eight basic mathematics competences defined in the KOM project. We will use these competences as a rubrics descriptor to evaluate each activity from the point of view of the core competences. When a student work is given with a numerical evaluation (punctuation), he/she may not know how to improve his/her performance on future assignments. Rubrics provide a description at each level of competence as to what is expected and explain the students why they received a specific score and what they should improve.

Rubrics can be adapted or created for a variety of purposes in assessment procedures. The most useful rubrics for promoting learning in the classroom have been called instructional rubrics (Andrade, 2000), analytic-trait rubrics (Arter and McTighe, 2001; Wiggins, 1998), and skill-focused rubrics (Popham, 1999).

We are specifically concerned with the type of classroom rubrics which use generic traits as analytic performance criteria to describe the acquisition or development of the mathematical competences.

According to Stiggins (2001), rubrics can teach as well as evaluate when used as part of a formative, student-centered approach to assessment, rubrics have the potential to help students develop a "vision of success" as well as "make dependable judgments about the quality of their own work". Andrade (2001) concluded that simply handing out and explaining a rubric was associated with higher scores on one out of three essays written by the students. A recent study by Hafner and Hafner (2003) provides additional evidence that undergraduate students can be effective users of rubrics and also the rubrics are a reliable tool for peer rating and an effective strategy for teaching and learning in the context of a college science classroom. Schafer et al. (2001) speculate in their study that higher test scores are the result of teachers having incorporated "operational definitions of achievement" into their instruction in ways that were understood and used by students.

Summarizing, rubrics helps both professor and student aiming to speak a common language and to translate an abstract concept as is a grade to a quantification of performance and behavior (Montgomery, 2000; Moskal, 2000; Villa, Poblete et al., 2007).

5.3 Binary assessment of activities based on competences

The usual evaluating of student activity by giving them back a quantitative grade. In our proposal, instead of giving back a grade, we evaluate how the impact of this activity contributes on the overall competence. In order to make this estimation we need to know the relationship between the activity and the eight competences. More precisely how much of each competence is embedded or comprised in the execution of the activity. In this sense, we follow the concept of constructive alignment which refers to the idea that students construct knowledge through relevant learning activities (Biggs, 2003).

Different activities have different impacts on each of the eight competences (Alpers and Demlova, 2012). For instance, a theoretical question is more intensive in competences of the first cluster whereas a calculus activity is more involved in representing mathematical activities, handling mathematical symbols and maybe making use of calculus tools. Then, a task consists in making an estimation on how each competence is involved in the execution of an activity or kind of activities distributing these impacts in weights on 1 basis (1-weighted) or 100 basis (100-weighted). In order to do that, we need a database of typified activities, as it is established in the aims of Chapter 8 of the KOM project where the matrix subject x competences is described.

Then, it will be possible to analyse from a binary point of view the development of the activity by each one of the eight competences according to Table 5.1, where "impact" $a_{\#i}$ represents the relevance of each competence C_i in the development of the activity $A_{\#}$, $1 \leq i \leq 8$, and "evaluation" is a binary indicator that represents whether the objective of the activity has been covered or not correctly.

	Competences to assess in one activity							
Activity ($A_{\#}$)	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Impact	$a_{\#1}$	$a_{\#2}$	$a_{\#3}$	$a_{\#4}$	$a_{\#5}$	$a_{\#6}$	$a_{\#7}$	$a_{\#8}$
Evaluation	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1

Table 5.1: Activity impact on basic competencies

In this way we obtain an activity quantitative grade $\boldsymbol{G(A_{\#})} = \sum_i \boldsymbol{a_{\#i} e_{\#i}}$ where $\overline{\boldsymbol{a_{\#}}}$ is a vector which represents the impacts from the activity $A_{\#}$ on the basic competences and $\overline{\boldsymbol{e}}$ is the binary evaluation vector.

We will call this method a binary assessment of an activity which is not disruptive with the standard methods that assign a grade based upon the outcome of the student and considerations about the quality of the execution. These considerations are very likely to involve personal appreciations from evaluators while a binary assessment tends to eliminate this effect. Tuning adequately the impact weights we may facilitate obtaining similar results from different evaluators. An adequate study of the impact of different activities in the development of the different competences should undoubtedly help us to design more competence oriented curricula. Clearly, these quantifications should be done in the context of teachers' communities in order to get a normalized procedure of assessment and always following standardized criteria like the ones exposed in the KOM project.

For example, let us suppose an activity consisting in calculating the volume of a solid of revolution. How do we punctuate this activity in a scale 0 to 10 if the result of the calculation is wrong? The result of the evaluation depends on the criterion of evaluation. If there is a based criterion that an engineer must generate accurate calculations, for obvious reasons, the score will be 0. Since students are in a learning progress, the order of magnitude of the error should be assessed from a very large mistake (the student does not have a common sense of magnitude) with a very low score or a small error with a score medium/high. But is this appreciation appropriate? Will the student make similar mistakes in the future because he/she does not have calculus skills or has it been a timely mistake? If the integral is well resolved, has the error been arithmetic?

There may be a great diversity of causes to analyse. Very detailed assessing activities suppose a lot of time consuming effort making unfeasible the introduction of many activities in the assessment process. Following a pattern based on the weights assigned to each competency, which can be described in terms of rubrics, the task is simpler, more automatable, prone to include in systems of self- or peer-assessment and even using automated systems.

A possible scoring following an activity-pattern assessment in case of a calculation error is shown in the next example:

	Weigh	Eval.	Score	Comments
M11	5	1	5	Student recognizes the solid of revolution and applies the adequate integral
M12	5	1	5	Student reasons the problem and applies correctly the integration limits
M13	20	**0**	0	The calculation results are wrong
M14	0	0	0	Not applied
M21	20	1	20	The representation of the object solid of revolution is correct
M22	40	1	40	The formal approach is correct and well developed
M23	10	1	10	The problem's wording is adequate and understandable.
M23	0	0	0	Not applied
	100		**80**	

However, if the error is deeper and indicates deficiencies in the development of the procedure of calculation, the scoring should be:

	Weigh	Eval.	Score	Comments
M11	5	1	5	Student recognizes the solid of revolution and applies the adequate integral
M12	5	1	5	Student reasons the problem and applies correctly the integration limits
M13	20	**0**	0	The calculation results are wrong
M14	0	0	0	Not applied
M21	20	1	20	The representation of the object solid of revolution is correct
M22	40	**0**	0	The formal approach is not correct and contains handling errors
M23	10	1	10	The problem's wording is adequate and understandable.
M23	0	0	0	Not applied
	100		**40**	

Let us observe that each evaluation affects different deficiencies or gaps in relation to different competencies.

We may say that binary assessment is an assessment by rubrics where execution scores are binaries. We are mapping rubrics scores into two categories true/false from the point of view of the eight basic competencies. Carr (2000, p. 55) states that different rubric “scores” represent a difference in the quality of the student work, not the quantity. In any case, we use a similar computational method to convert binary rubrics into “vector scores” not in “scores”. The main difference lies in the method of calculation of the final scores. We introduce different weights according to the typology of activities developed in each topic from the point of view of the achievement of competencies. Then, it may be concluded with the generation of a final score that represents an estimate of the overall consecution of the objectives of the course.

The different competences can be described by means of the use of rubrics both of a general form and of a form adapted to the type of activity, independently whether a binary scale is used for its evaluation.

In one activity we measure what contribution or impact has its execution in the development of individual competences at the individual level of the activity itself. But this is independent of the system of evaluation followed to conclude that the contribution to a particular competence achieved has been successful or not. And since true/false appreciation is issued on the contribution, it seems that the rubrics method is the most appropriate to describe this contribution.

Thus for example, in the problem of cable which coils up a cylinder, described in Section 3.4.4, the proposed question was "*Find the exact integer number of mm that there must be between spires in order to use as little amount of cable as possible*". To assess this question from the point of view of competences we could write some rubrics such as:

- M11: The problem is thought over an algebraic problem of integer numbers
- M12: Student concludes the need to look for a such number that "must be the minor divisor of"
- M13: The correct solution is calculated.
- M14: Not included
- M21: Not included
- M22: Student makes proper use of mathematical symbols
- M23: Student writes down the reasoning followed with clarity (i.e. , it is understood)
- M24: Not included

It could be assigned the weights (30, 10, 40, 0, 0, 10, 10, 0) giving greater importance to discover that it is a problem of integers numbers and divisors (student's ability to think mathematically) and to calculate the right solution (calculation ability). Smaller relevance is scored to the ability of developing the problem (yet centered) and using appropriate mathematical symbols and write (communicate) it properly so that other people could understand the solution applied.

This evaluation approach is very specific for this problem because. In practice, there may be written sets of binary rubrics of more general spectrum applicable to a similar set of activities and must be attached with the delivery of the activities so that the students are able to know the criteria of evaluation without being so explicit as in M11 and M12.

5.4 ATC components

In the KOM project, Chapter 9 (Niss and Højgaard, 2011) it is declared that t*he core of a competency is an insight-based readiness to act, where "the action" can be physical and behavioural – including oral – as well as mental. A valid and comprehensive assessment of a person's mathematical competencies must therefore, as a starting point, be based on identifying the presence and extent of these features in relation to the mathematical activities in which the respective person has been/is being involved.* And also that *a mathematical activity can, for example, be to solve a pure or applied mathematical problem, to understand or construct a concrete mathematical model, to read a mathematical text with the view of understanding or acting on it, to prove a mathematical theorem, to study the interrelations of a theory, to write a mathematical text for others to read, or to give a presentation.*

Then, we could extend the binary assessment of one activity to a binary assessment of sets of activities and their relations with the eight competences.

There are different kinds of activities that are relevant to get an adequate student's training on their way to achieve the objective level of competences in a course programme. These kinds of activities are lectures, assignments, laboratories, individual or group projects, working groups, tutorials, presentations, etc.

Each kind of activity presents different impact spectrums on the eight competences. The SEFI Framework for Mathematics Curricula in Engineering Education developed a very interesting study about the relationship between kinds of activities and competences along its Chapter 4, (SEFI Mathematics Working Group, 2013).

Then, we may extend Table 5.1 to Table 5.2 about competences to assess one activity to a master table about impacts on competences of type of activities of a specific topic of the programme. So, each type of activity *i* (lectures, exams, labs, etc…) has an impact a_{ij} over each of the eight competences C_j. Additionally, each of the type-activities has a w_i impact or weight on the "topic" T that is being evaluated.

	Topic (T)	Impacts on competences of type-activities							
	Activities	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
w1	Lectures	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}
w2	Exams	a_{21}	a_{22}	a_{23}	a_{24}	a_{25}	a_{26}	a_{27}	a_{28}
	….								
wn	Activity type n	a_{n1}	a_{n2}	a_{n3}	a_{n4}	a_{n5}	a_{n6}	a_{n7}	a_{n8}

Table 5.2: Activity/Topic impacts on basic competences

Table 5.2 is a master table because two different activities belonging to the same type could have different impacts on the competences due to its extension or complexity. The master table serves as a reference and minor tuning might be done in specific activities. In this sense, a type-activity can be split into two or more subclass-activities or consider each subclass-activity as a type-activity.

A course topic is covered by, let us say, of different sets of type-activities. Then, a quantitative grade of the topic is T obtained by means of the expression $\boldsymbol{G(T)} = \frac{\sum_i \boldsymbol{w}_{\mathbf{i}} \boldsymbol{G(A_i)}}{\sum_i \boldsymbol{w_i}}$, where $\boldsymbol{w}_{\mathbf{i}}$ is the weighted relevance of the activity in the topic T.

Finally, the list of topics to be studied in a course represents a third dimension in the model and, again, each of them has a different relevance that can be represented with a specific weight.

Then, a final grade can be calculated with the expression $\boldsymbol{FG} = \sum_i \boldsymbol{p}_{\mathbf{i}} \boldsymbol{G(T_i)}$, where $\boldsymbol{p}_{\mathbf{i}}$ is the percentage 100-weighted relevance of the topic on the subject.

To round off, an ATC cuboid is a three-dimensional matrix containing the relationship between activities, topics and competences which are quantified assigning a weight in each combination competence, topic, and activity. Each element a_{ijk} in the ATC matrix is a compound weight corresponding to the product of the activity A_i impact on the T_j topic weighted on the contribution to C_k competence. This ATC cuboid is a master cuboid, henceforth denoted mATC, since it contains the weights that allow us to generate measures of the execution of student's activities.

5.5 Personal ATC cuboids

A personal ATC cuboid, hereinafter pATC, is an empty ATC cuboid assigned to each student at the beginning of a course programme. The three dimensions contain the eight basic competences or a subset or combination of them that are going to be filled during the course on the OZ axis. The OX axis contains a set of primary entrances corresponding to different class-activity to execute and the OY axis contains entrances corresponding to the list of topics.

On OX axis we represent the collection of activities to be executed in the two levels (type and subclass) mentioned above. Since each subclass can have one or more executions, an aggregated of all executions is represented.

On OY axis we represent each topic within the syllabus. Thus, a point at plane OXY represents some relationship between an activity and a given specific topic. This interpretation is an organizational representation and not a geometrical or analytical representation.

On OZ axis we represent each of the eight basic competences. When an activity is executed an eight-component vector is produced and it is allocated on the OXY point representing the relationship between activity and topic.

A moment of evaluation is represented by a set of activities on a time interval grouped into a discrete measure. Grading is a discreet process that comes from pictures taken through moments of evaluation carried out by means of activities, lab classes, exams, etc.

The binary assessment of the execution of an activity produces a vector to be pushed into the pATC. The binary components corresponding to the competences are multiplied by the weights of the subclass-activity at the moment of evaluation and pushed into the cuboid.

As a subclass-activity can be executed several times on the same moment of evaluation, we have to save the number of occurrences within each subclass-activity. Thus, a new row to be pushed into the cuboid must be averaged with the current vector values by using the activity executing frequency.

A moment of evaluation may consist of the execution of one activity or many activities of different types and subclasses belonging to one or more topics. In order to avoid building a very complex model, we are assuming that a formative moment of evaluation is when a simple activity is executed while a summative moment of evaluation implies the execution of a specific type-activity (exam) consisting in one or more activities, executed and evaluated, generating an aggregated grade to assign to the moment of evaluation.

Taking into account all the activities to be executed by students during a course and pushing all of them into pATCs with binary assessment, we have a tool to implement continuous assessment based on competences. Grading moments of evaluation in different time instants could plot a great variety of assessment graphics representing the continuous assessment process.

Finally, as the course progresses the students increase their overall knowledge on the subject. Thus, a well-executed activity should have a greater and positive impact on the global results in order to redeem past gaps. Conversely, a poorly-executed activity also should have a greater negative impact on the global results if it was assumed that the student has already achieved a good performance on the subject.

In this sense, we introduce the *grade impact amplifier as continuous assessment procedure, hereinafter* $GIA|_{CAP}$, as a new instrument to reflect the greater level of competence or general knowledge developed throughout the course. It consists of defining a set of increasing weights to average the new activity-rows to be pushed into the personal cuboids. This may be done by means of two or three $GIA|_{CAP}$ states after each summative moment of evaluation in order to stablish different stages along the programme. Anyway, we could stablish $GIA|_{CAP}$ only in the positive case as a student motivation tool to promote the continuous effort on the whole subject.

The key goal is to design an ATC cuboid well balanced and weighted that allows us to compute each of the execution vectors. The ATC cuboid must be carefully designed, activity by activity, topic by topic, based on historical data for the same subject and tuned each course by means of feedback of the obtained results.

5.6 Grading and targeting with ATC cuboids

As time goes by, the pATCs are filled with the results of binary assessment of different activities. Aggregating pATCs we can obtain group grades for activities, topics, competences, or any other combination.

For example, we can obtain a global course grade for a specific topic applying the weights of the competences to all the activities executed for this topic by all students. We could also study the development of a competence or a comparative between competence's developments by means of aggregating partial or total pATCs.

At one point in time, the pATC represents somehow the situation of development of competences and knowledge of the student regarding the given knowledge or course advance. Beyond a simple scalar grade, the internal structure of the cuboid shows a radiograph of the relationship between the different knowledge items that the student should master. And with this very specific knowledge about the student progression, it is possible to establish and to individualize the strategy that allows achieving general progress in the objective development of the competences within the course programme. Therefore this abides this methodology as a valid tool to address mathematical deficiencies with advanced diagnostic testing (Carr, Murphy, Bowe and Fhloinn, 2012).

On the other hand, we can put our educational objectives into precompiled cuboids to establish different target levels that we could denominate target ATCs. The tATCs, in this sense, are references to be achieved and they are the tools to build up the individualized strategies with the aim of reaching the course objectives. Targeting is a way to predict future results and in this sense there are some studies which intend getting some class of predictors (Shortera and Young, 2012). Other studies are based on daily execution of activities as quizzes and tests in order to study the continuous progression as an estimation of final results (Mawhinney *et al.,* 1971)

Aggregating pATCs allow us to obtain a general course construct to study the development of the competences within the whole student collective and their relationships between the knowledge items. This is a good tool to obtain feedback on the right evolution of the targeting's.

Given that the pATC construction is additive, we can obtain different metrics defining activity sets joining all the desired binary activity vectors and generate new ATCs cuboid form them.

Conversely, we could mitigate the effect of a wrong evaluation pushing the same activities with binary negative values and computing again the ATC.

6 A comparison between ATC methodology and traditional evaluations

6.1 Introduction

In this chapter, we present a comparison between the evaluation method based on ATC cuboids and the evaluation applied to students of Mathematics I at ETSID of Univesitat Politècnica de València.

Currently, the ETSID already applies a component of retroactivity because in the last exam of the course some questions referring previous topics are included. This has the effect of a shifted re-evaluation of the grade obtained in them.

The comparison has been made on a small sample of students with different final grades. Previously we will detail how the ATC cuboid are generated with the data of a student from the studied sample.

The goal is to check if there are significant deviations between both methods in terms of final grades. A non-significant deviation of results would be important so that the assessment following the ATC method does not bring out a drastic change of evaluation rules and results while at the same time the ATC method carries out a wealth of information.

If the ATC cuboids methodology is going to be applied to a large number of students and with a large number of activities, a computing software is very much needed for an adequate data treatment. This also has other important capabilities such as recording the student's performance and cataloging activities, providing continued feedback in time to the students, analyzing data about learning evolution and skills development and discovering patterns of behavior as well that will allow us to improve the management of the course.

6.2 Competences

We are going to cluster the eight competences by grouping them into four characteristic facets whose composition and description is as follows in order to facilitate the evaluation tasks,

- CC_1: Capacity of reasoning (M11 & M12). We include the competences "thinking mathematically" and "reasoning mathematically". To evaluate this competence we will observe if the student has been capable of placing the mathematical problem in other scientific contexts and that in its development follows an adequate chain of reasoning.
- CC_2: Ability to solve problems (M13 & M14). We include the competences "Posing and solving mathematical problems" and "modeling". We evaluate the problem solving capacity paying attention to the procedure of calculation and the accuracy of the results. Posing problems and modeling are usually involved with more complex and complete assignments.
- CC_3: Use of formal language and communication (M21 & M22 & M23). We include the competences "representing mathematical entities", "handling mathematical symbols and formalism" and "communicating in, with and about mathematics". Evaluation of this cluster requires observing if the symbolic language is used correctly. In addition, the representation of entities and mathematical objects is correct and appropriate to the context of the activity. Moreover we will observe the use of written language or oral language where appropriate, evaluating if the communication is understandable and contains the expected lexis.
- CC_4: Use of tools and aids (M24). In this case what is evaluated is the correct use of scientific computing programs, calculators, measuring instruments, etc… appropriate to the resolution of each specific activity.

6.3 Sample and elements to assess. Master ATC

With the aim of making a comparison we have been selected activities of seven of the 120 students that have followed the course and have obtained different final results:

- Two students reached an A-level, one of them with an A+ and the other one with a standard A.
- Two students with a C-level. Again, one of them with a C-high and the other one with a C-low.
- Two students with a D-level, high and low.
- Finally, a student with an F-level.

The subject of the course covers four sections or topics:

- Calculus I (C1), dedicated to the study of real functions of one variable, derivatives, integration and their applications.
- Calculus II (C2) including the study real functions with two or more variables, partial derivatives, multiple integral and their applications.
- Linear Algebra (A) which contains material oriented to matrix calculus and resolution of linear system and matrix diagonalization.
- Series (C3) introducing the study of numerical series, power and Fourier series.

Additionally, the course is completed with some practical activities:

- A set of 27 sessions of laboratory practices with the use of the computer algebraic system Mathematica.
- Two exams concerning laboratory practices.
- Two assignments to do out of the classroom with a control test inside the classroom

In Section 4.4 there is a complete description of the structure of the course in topics and activities.

The composition of the set of activities of the course grouped by topics and moments of evaluation has the following structure

- MoE C1 consisting of a test with 12 questions and a written exam containing 6 questions.
- MoE C2 is a written exam containing 7 questions.
- MoE A with a written exam of 7 questions.
- MoE C3 with 4 questions about numerical series, 2 questions concerning C1 and another 2 questions concerning C2.
- MoE LP consisting of 27 laboratory sessions
- MoE ExLP two exams, Lex1 and lex2, about lab practices.
- MoE T with two assignments consisting in groups of activities to do out of the class with multi-choice control tests inside the classroom.

In order to implement an activities backlog, for each MoE, each question has been turned into an activity. As the different questions had different assigned punctuations according to its extension and/or complexity, subclasses of activity have been created for each of these situations. With this structure it has been built a master ATC that allows us to apply the ATC method of evaluation.

Topic	**Weight**	**Activities**	**SubWeight**	**Subclass**	CC_1	CC_2	CC_3	CC_4	Total
C1	10	**Test**	100	P11	60	30	10	0	100
7,50%	90	**Exam**	30	E11	40	30	30	0	100
			30	E12	40	30	30	0	100
			40	E13	40	30	30	0	100
C2	100	**Exam**	60	E21	40	30	30	0	100
14,25%			40	E22	40	30	30	0	100
A	100	**Exam**	60	E31	40	30	30	0	100
15,75%			40	E32	40	30	30	0	100
C3	100	**Exam**	60	E41	40	30	30	0	100
30,00%			40	E42	40	30	30	0	100
			40	E43	40	30	30	0	100
LP	30	**Lab**	100	L11	0	0	20	80	100
25,00%	28	**Lex1**	100	L21	20	10	10	60	100
	42	**Lex2**	100	L31	20	10	10	60	100
			100	L32	20	10	10	60	100
T	50	**Assig1**	100	T11	30	20	20	30	100
7,50%	50	**Assig2**	100	T21	30	20	20	30	100

6.4 Retroactivity

As we have aforementioned in the introduction, in Mathematics I at ETSID already is applied a concept of positive retroactivity embedded in some of the topics covered by.

- MoE C3 punctuates the knowledge about numerical series with 4 points and also contains two sections relating to C1 and C2 topics with a score of 3 points each one. These two sections involve a supplement of grade for the C1 and C2 exams when their question are properly developed and the students fulfill certain conditions.
- The second exam of laboratory practices also involves a positive component of retroactivity on MoE A (Algebra) and the final grade of PL.

To apply the retroactivity it has been implemented four binary switches to indicate the fulfillment of each of these four conditions. These indicators take the value 0 if:

- AL_ok (Algebra) if a minimum of three points are obtained in the theoretical or practical exam of algebra.
- C1_OK If a minimum of three points are obtained in C1 or in the part C1 of C3 scaled up 10 points (to multiply the grade C1(C3) x 10/3).
- C2_OK if a minimum of three points are obtained in C2 or in the part C2 of C3 scaled up 10 points (to multiply the grade C2(C3) x 10/3).
- S_OK (Numerical series) if there is obtained at least 1 point (of 4) in the part of numerical series of C3.

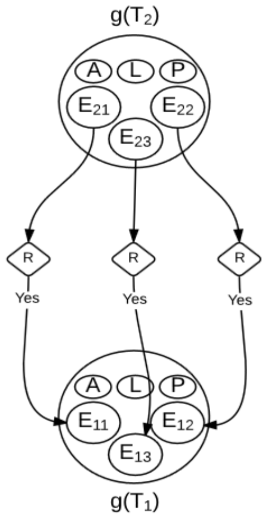
The four indicators are added on a new indicator All_OK which has the value 0 for a student if he/she has met the four conditions.

To apply the retroactivity to each of the corresponding parts it is required the indicator All_Ok = 0 plus an additional condition for each MoE. Namely:

- C1R (retroactivity on C1)
  All_oK=0 and grade C3(C1)*10/3 > max(5, grade C1)
- C2R (retroactivity on C2)
  All_oK=0 and grade C3(C2)*10/3 > max(5, grade C2)
- ALR (retroactivity on A)
  All_oK=0 and grade PL2(A)*10/5,4 > max(6, grade A)
- PL1R (retroactivity on PL1)
  All_oK=0 and grade PL2 > MAX(5; grade PL1)

As we have defined in the chapter of binary assessment, the retroactivity assumes that the execution of an activity could have consequences for the execution of past activities in a positive or negative manner. We have defined conceptually the retroactivity as a contribution from a moment of evaluation toward other moments of evaluation predecessors. Now we are going to give a feasible algorithm to implement this concept.

There could be followed very different strategies to implement the retroactivity. In addition, could be defined only when it is positive as a motivation plus for students to redeem a previous unsuccessful moment of evaluation. On the other hand, we will introduce the retroactivity only in collections of activities of summative evaluation. It could be extended to any type of activity but it seems more natural to do so.



A right strategy is to analyze the nature of the activities of a moment of evaluation and to establish retroactivity flows when an activity covers all the skills needed in the execution of the previous activities. Also, the retroactivity can act on one or more of the competences involved in the execution of the activity.

Additionally, we can define a set of rules that decide whether triggers or not a retroactivity workflow. For example, let us suppose a problem of flat areas resulting in a definite integral of a trigonometric function. If the antiderivative is well resolved we could apply a positive retroactivity on integration methods of trigonometric functions.

Since the ATC cuboids system allows a streaming evolution of binary assessment vectors, for each activity that is correctly executed according to defined rules, the system could issue evaluation vectors toward past moments. Given that it is an additive and contributory system, the issuance of these vectors will improve the grade obtained in previous moments and about the predecessor's materials.

In the sample which we are studiying if the rules are met then binary vectors are emitted to the topics on which the retroactivity have to actuate.

The rules applied in this comparative are the followings:

- Activities E42 throw activities E12 and E13
- Activities E43 throw activities E22
- Activities L32 throw activities E32

Retroactivity rules are triggered if the grade of the activity is greater than 40 % with a $GIA|_{CAP}$ = 1 and with a $GIA|_{CAP}$ = 2 if the activity grade is greater than 75 %. Each retroactivity rule generates a binary vector with all components equal to 1 (grade 100%) on the moment in which it applies.

We should not make a variation in the weights of the master ATC since that would imply a change of rules of evaluation for all the students. Master ATCs should be defined at the beginning of the course and keep them throughout the academic year. Due to the additive nature of the pATC, a *grade impact amplifier,* $GIA|_{CAP}$ of order p (p positive integer) can be implemented introducing p identical assessment vectors for each activity execution. Thus, it remains the property of continuity of the evaluation process, so that each execution has an impact p times higher while keeping the previously obtained results and accelerating the average convergence to the end results.

One of the problems of $GIA|_{CAP}$ is the negative impact amplification of failed executions. The possible right combination is to apply the retroactivity in association with $GIA|_{CAP}$. Thus, after a moment of summative evaluation, it can set up a $GIA|_{CAP}$ so that each activity generated by the process of retroactivity triggered by rules of success execution, has a major and positive impact on previous results.

Also, another possible situation where the accelerators are a useful application is in performing recovery tasks specifically assigned to students who need to redeem failed previous executions.

6.5 An implementation of the ATC evaluation

Next, we are going develop the ATC assessment method for student C1 of the sample. Along this development we will explain how the different elements in ATC cuboids are calculated.

6.5.1 Activity backlog

The different topics have been converted into binary vectors building the corresponding backlog of activities with the grade obtained in each of the activities.

Each activity has been reevaluated applying the criteria exposed in the ATC method using the existing material at ETSID (written exam, electronic register of laboratory practices, etc…). We will explain some of them to illustrate the obtained results.

MoEv 1 covers the topic C1 consisting of an assignment and a multi-choice test of 12 questions and a written exam with 6 questions. The backlog table for this moment is as follows. The meaning of the columns and acronyms used is explained in detail right after.

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	C1	C1	Test 1	100	P11	0	0	0	0	0	0	0	0	0
2	1	C1	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	C1	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	C1	C1	Test 4	100	P11	0	0	0	0	0	0	0	0	0
5	1	C1	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	C1	C1	Test 6	100	P11	0	0	0	0	0	0	0	0	0
7	1	C1	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	C1	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	C1	C1	Test 9	100	P11	1	1	1	0	60	30	10	0	100
10	1	C1	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	C1	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	C1	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	C1	C1	Exam 1	30	E11	1	0	1	0	40	0	30	0	70
14	1	C1	C1	Exam 2	30	E12	1	0	1	0	40	0	30	0	70
15	1	C1	C1	Exam 3	30	E11	1	1	1	0	40	30	30	0	100
16	1	C1	C1	Exam 4	40	E13	1	1	1	0	40	30	30	0	100
17	1	C1	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	C1	C1	Exam 6	30	E11	1	1	1	0	40	30	30	0	100

Some activities are evaluated as 0 because were left in blank or with all its components incorrectly answered.

The columns of the activity backlog have the following meanings:

» Act. N.

The activity number N indicates the numerical order in which it is executed by the student. Anyway, the order does not have effect, in general, on the computing ATC method except when we can obtain an image of the ATC in a given instant of time.

» MoEv

The moment of evaluation. We use the MoEv as an aggregator of activities in order to generate a grade for a topic or set of topics like the C1, C2, C3, A, PL and T.

The order of activities does not have effect on the MoEv calculus. We can add activities to a MoEv in any time instant and in any order. For example, retroactivity generates shifted vector activities on time. In that case, we need to recalculate the entire ATC and the activities will compute in their corresponding MoEv.

» Student

The student's pATC.

» Topic

An identification of the moment of evaluation. It could include a topic or group of topics of the subject. The topics are created by the teacher criteria.

» Activities

The types of activities to be executed like written exams, lab practices, etc…

» Weight

The weight or relevance of the activity subclass within the topic. This weight is obtained from the Master ATC SubWeight column joined by the subclass identifier.

» Subclass

An activity subtype identifier. The second char refers to the activity and the last char to the subclass activity. As we will see in the ATC computing, the second char is used to aggregate data from all the activities Amn with the same value of Am.

The reason to create subclasses is a consequence to the existence of question with different extension or complexity which allow us to assign different weights or relevance to each group of activities.

» CC_i

The binary evaluation assigned to each of the four clusters defined. If the cluster criteria is evaluated positively they take the value 1 else a zero value is given.

» wc*CC_i and A. grade

This value is the product of the binary evaluation of the cluster CC_i by the weight assigned to the pair Activity Subclass – Cluster in the Master ATC. The sum of this values is the grade of the activity.

MoE 2 covers the topic C2 consisting in a written exam with 7 questions. The backlog for this moment is as follows:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	C1	C2	Exam 1	60	E21	0	0	0	0	0	0	0	0	0
20	2	C1	C2	Exam 2	60	E21	1	1	1	0	40	30	30	0	100
21	2	C1	C2	Exam 3	60	E21	0	1	0	0	0	30	0	0	30
22	2	C1	C2	Exam 4	40	E22	1	1	1	0	40	30	30	0	100
23	2	C1	C2	Exam 5	60	E21	0	0	0	0	0	0	0	0	0
24	2	C1	C2	Exam 6	60	E21	1	1	1	0	40	30	30	0	100
25	2	C1	C2	Exam 7	60	E21	0	0	0	0	0	0	0	0	0

For example, the activity 21 was poorly argued which could indicate a bad understanding of mathematical concepts underlying (CC_1 = 0). However, the mathematical problem was well solved, maybe the student had learned the procedure making repetitions (CC_2=1). As expected, the problem wording was unclear (CC_3=0).

Activity 23 was left in blank.

MoE 3 covers the topic A consisting in a written exam with 7 questions. The backlog is as follows:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	C1	A	Exam 1	60	E31	1	1	1	0	40	30	30	0	100
27	3	C1	A	Exam 2	40	E32	0	0	1	0	0	0	30	0	30
28	3	C1	A	Exam 3	60	E31	1	1	1	0	40	30	30	0	100
29	3	C1	A	Exam 4	60	E31	1	1	0	0	40	30	0	0	70
30	3	C1	A	Exam 5	60	E31	1	1	1	0	40	30	30	0	100
31	3	C1	A	Exam 6	60	E31	1	1	1	0	40	30	30	0	100
32	3	C1	A	Exam 7	60	E31	1	1	1	0	40	30	30	0	100

For example, the activity 29 was correctly argued and resolved, however it redaction was poorly written.

MoE 4 covers the topic C3 consisting in a written exam with 8 questions. The first four about numerical series, the next four ones about questions referred to C1 and C2. The backlog is as follows:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	C1	C3	Exam 1	60	E41	1	1	0	0	40	30	0	0	70
34	4	C1	C3	Exam 2	60	E41	1	1	0	0	40	30	0	0	70
35	4	C1	C3	Exam 3	60	E41	1	1	0	0	40	30	0	0	70
36	4	C1	C3	Exam 4	60	E41	1	1	1	0	40	30	30	0	100
37	4	C1	C3	Exam 5	40	E42	1	1	1	0	40	30	30	0	100
38	4	C1	C3	Exam 6	40	E42	1	1	1	0	40	30	30	0	100
39	4	C1	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	C1	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

An exam well executed in general with some lacks of written communication.

MoE 5 covers the sessions of laboratory practices and two laboratory exams. The backlog for these groups of activities is as follows:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	C1	PLS	Session01	100	L11	0	0	0	0	0	0	0	0	0
42	5	C1	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	C1	PLS	Session03	100	L11	1	0	0	1	20	0	0	80	100
44	5	C1	PLS	Session04	100	L11	1	0	0	1	20	0	0	80	100
45	5	C1	PLS	Session05	100	L11	0	0	0	1	0	0	0	80	80
46	5	C1	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	C1	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	C1	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	C1	PLS	Session09	100	L11	0	0	0	1	0	0	0	80	80
50	5	C1	PLS	Session10	100	L11	0	0	0	1	0	0	0	80	80
51	5	C1	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	C1	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	C1	PLS	Session13	100	L11	0	0	0	1	0	0	0	80	80
54	5	C1	PLS	Session14	100	L11	0	0	0	0	0	0	0	0	0
55	5	C1	PLS	Session15	100	L11	1	0	0	1	20	0	0	80	100
56	5	C1	PLS	Session16	100	L11	0	0	0	1	0	0	0	80	80
57	5	C1	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	C1	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	C1	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	C1	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	C1	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	C1	PLS	Session22	100	L11	1	0	0	1	20	0	0	80	100
63	5	C1	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	C1	PLS	Session24	100	L11	1	0	0	1	20	0	0	80	100
65	5	C1	PLS	Session25	100	L11	1	0	0	1	20	0	0	80	100
66	5	C1	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	C1	PLS	Session27	100	L11	0	0	0	0	0	0	0	0	0
68	5	C1	PL1	ExLab1	100	L21	0	0	1	1	0	0	10	60	70
69	5	C1	PL2	ExLab2	100	L31	1	0	1	1	20	0	10	60	90
70	5	C1	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

In order to evaluate the lab sessions we have read the electronic register produced by PoliformaT platform. Each activity consist of ten calculus question on average to be resolved with a CAS program writing the result on the computer questionnaire. We have assigned CC_1 with a weight of 20% to evaluate the comprehension of the problem and CC_4 with 80% to evaluate the execution of the calculus with the CAS platform.

In Lab exams we have considered the four clusters.

MoE 6 refer to two assignments with their corresponding control tests. The backlog is as follows:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	C1	TA1	Task1	100	T11	1	0	0	1	30	0	0	30	60
72	6	C1	TA2	Task2	100	T21	1	0	0	0	30	0	0	0	30

6.5.2 Retroactivity

Applying the rules aforementioned in previous section, the execution of the activities of student C1 generates the following retroactivity vectors:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
37	4	C1	C3	Exam 5	40	E42	1	1	1	0	40	30	30	0	100
38	4	C1	C3	Exam 6	40	E42	1	1	1	0	40	30	30	0	100
39	4	C1	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	C1	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

Both activities E42 have a grade greater than 75%. Then, the first E42 activity generates a 100% E12 activity x 2 and the second E42 generates a 100% E13 activity x 2.

The first E43 (grade > 75%) generates two E22 and the second E43 (40 ≤ grade ≤ 75) generates one E22.

Finally, the lab exam activity L32 generates two E32 retroactive activities.

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
70	5	C1	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Thus, the backlog generated by the retroactivity is as follow:

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	C1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	C1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	C1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	C1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	C1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	C1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
79	7	C1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
80	7	C1	Retro	A	40	E32	1	1	1	0	40	30	30	0	100
81	7	C1	Retro	A	40	E32	1	1	1	0	40	30	30	0	100

6.5.3 Personal ATC cuboid

The ATC personal cuboid, pATC, is initially empty. As the student is executing activities, his/her evaluations have to be pushed into pATC which evolves after each activity.

We will show pATC table split into two tables. The first one is used to calculate the grade of each type of activity, clusters, topics and the final grade of thee course. The second one contains auxiliary calculus used in grades, effectiveness and normalization of levels of achievement of competences.

The pATC of student C1 after the execution of all activities from the backlog and the meaning of all columns and rows is as follows:

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	**Start:**	1	**End:**	81						**80.2**	**57.3**	**90.4**	**83.5**	**85.1**	**45.0**	**78.1**	**78.1**
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_2)$**	**$g(CC_3)$**	**$g(CC_4)$**	**$g(A_t)$**
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	10	330	9	7	9	0	12,000	7,200	9,000	0	36.4	21.8	27.3	0.0	85.5
C2	100	Exam	E2	10	520	6	7	6	0	11,200	10,200	8,400	0	21.5	19.6	16.2	0.0	57.3
A	100	Exam	E3	9	480	8	8	8	0	17,600	13,200	12,600	0	36.7	27.5	26.3	0.0	90.4
C3	100	Exam	E4	8	400	8	8	4	0	16,000	12,000	5,400	0	40.0	30.0	13.5	0.0	83.5
PL	30	Lab	L1	27	2,700	19	0	0	24	38,000	0	0	192,000	14.1	0.0	0.0	71.1	85.2
PL	28	Exam	L2	1	100	0	0	1	1	0	0	1,000	6,000	0.0	0.0	10.0	60.0	70.0
PL	42	Exam	L3	2	200	2	1	2	2	4,000	1,000	2,000	12,000	20.0	5.0	10.0	60.0	95.0
T	50	Assig	T1	1	100	1	0	0	1	3,000	0	0	3,000	30.0	0.0	0.0	30.0	60.0
T	50	Assig	T2	1	100	1	0	0	0	3,000	0	0	0	30.0	0.0	0.0	0.0	30.0
					#Positive CC evaluations	58	35	34	28	128,800	55,600	42,400	213,000					
					Efectiveness	71.6	64.8	63.0	87.5									

The different columns and rows involved in the pATC cuboid have the next meanings:

» Topic

The ETSID identifier of the corresponding MoEv.

» Weight

The weight of the activity type within the topic. It is obtained from the master ATC (Weight Column). It is not necessary than they be 100-weighted.

» Activity and subclass

Same meaning as in the activities backlog.

» #Act

Number of activities executed in the subclass activity category.

» $D=\sum W_A$

Sum of the weight of each activity subclass within the activity type. This sum is obtained adding the column Weight from the backlog table.

$$D_t = \sum_{k=1}^{N_t} w_k^S$$

Where N_t is the number of activities executed in the group, w_k^S is the weight of the activity subclass (column weight from backlog).

It is used for averages calculus when new binary assessment vectors are pushed into the pATC.

» SCC_i

The sum of the corresponding CCi of the backlog table for the group of activities executed in topic t:

$$SCC_i^t = \sum_{k=1}^{N_t} CC_{ik}^t$$

Where N_t is the number of activities executed and CC_{ik}^t is the binary component of the cluster i in the topic t for the activity k.

» $wSCC_i$

The sum of the products of wCCi times the weight of each subclass activity.

$$wSCC_i^t = \sum_{k=1}^{N_t} w_k^S \cdot w_k^{CC_i,S} \cdot CC_i^t$$

where $w_k^{CC_i,S}$ is the weight of the activity subclass S within the cluster CC_i (obtained from master ATC) and CC_i^t is the binary component of the cluster I in topic t.

» $g(CC_i)$

It represents the grade obtained in cluster i for topic:

$$g(CC_i^t) = \begin{cases} \frac{wSCC_i^t}{D_t}, & D_t \neq 0 \\ 0 \quad , & D_t = 0 \end{cases}$$

» $g(A_t)$

It represents the grade obtained for the topic:

$$g(A_t) = \sum_{i=1}^{4} g(CC_i^t)$$

» **#Positive CC evaluations**

It is the sum of the columns SCC_i which represents the amount of positive evaluation of clusters CC_i obtained in the total set of activities executed.

» Effectiveness

The effectiveness is a ratio which represents how many positive evaluations have been obtained over the total number of activities executed.

We define SEf_i as the number of activities that can be executed and evaluated. They could be calculated as:

$$SEf_{i,k}^{t} = f(x) = \begin{cases} 1, & w_k^{CC_i,S} > 0 \\ 0, & w_k^{CC_i,S} = 0 \end{cases}$$

The number of total activities to be executed in a given cluster is the summa of SEF_i elements. Then, the effectiveness of a cluster i can be calculated as:

$$Ef_i = \frac{\sum_{k=1}^{\#t} SCC_k^t \cdot 100}{\sum_{k=0}^{\#t} SEf_k^t}$$

Where #t is the set of topics along the course.

» **Grades**

The grade for a given topic is the result of the evaluation of all the activities belonging to this topic. Then, the grade of a topic can be calculated as the average of the grades of subclasses in topic T.

$$g(T) = \frac{\sum_{k=1}^{N_S} w_k^S \cdot g(A_S)}{\sum_{k=1}^{N_S} w_k^S}$$

The final grade (FG) is obtained by averaging topics with their corresponding weights:

$$FG = \frac{\sum_{k=1}^{N_T} w_k^T \cdot g(T_k)}{\sum_{k=1}^{N_T} w_k^T}, with\ g(T_k) defined$$

Where w_k^T represents the weight of the topic T_k in the course programme. This FG is calculated from the topics which have yet been covered.

We also define a Contributive Final Grade as the Grade obtained from the beginning of the course till the current moment and it is a progression showing from 0 to final grade. Then:

$$CFG = \frac{\sum_{k=1}^{N_T} w_k^T \cdot g(T_k)}{\sum_{k=1}^{N_T} w_k^T}$$

With N_T is the number of topics and $g(T_k)$ the grade of the topic. If the topic has not been covered when the CFG is calculated, we consider $g(T_k) = 0$.

Next, we include the pATC in the seven moments of evaluation to illustrate the calculus procedures:

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	18						70.6	0.0	0.0	0.0	0.0	0.0	5.3	70.6
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
A	100	Exam	E3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
C3	100	Exam	E4	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	30	Lab	L1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	28	Exam	L2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	42	Exam	L3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
					#Positive CC evaluations	9	7	9	0	30,400	15,000	8,800	0					
					Efectiveness	50.0	38.9	50.0	0.0									

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	25						70.6	44.5	0.0	0.0	0.0	0.0	11.6	53.5
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	7	400	3	4	3	0	6,400	6,600	4,800	0	16.0	16.5	12.0	0.0	44.5
A	100	Exam	E3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
C3	100	Exam	E4	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	30	Lab	L1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	28	Exam	L2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	42	Exam	L3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
					#Positive CC evaluations	12	11	12	0	36,800	21,600	13,600	0					
					Efectiveness	48.0	44.0	48.0	0.0									

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	32						70.6	44.5	88.5	0.0	0.0	0.0	25.6	68.2
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	7	400	3	4	3	0	6,400	6,600	4,800	0	16.0	16.5	12.0	0.0	44.5
A	100	Exam	E3	7	400	6	6	6	0	14,400	10,800	10,200	0	36.0	27.0	25.5	0.0	88.5
C3	100	Exam	E4	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	30	Lab	L1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	28	Exam	L2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	42	Exam	L3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
					#Positive CC evaluations	18	17	18	0	51,200	32,400	23,800	0					
					Efectiveness	56.3	53.1	56.3	0.0									

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	40						70.6	44.5	88.5	83.5	0.0	0.0	50.6	75.0
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	7	400	3	4	3	0	6,400	6,600	4,800	0	16.0	16.5	12.0	0.0	44.5
A	100	Exam	E3	7	400	6	6	6	0	14,400	10,800	10,200	0	36.0	27.0	25.5	0.0	88.5
C3	100	Exam	E4	8	400	8	8	4	0	16,000	12,000	5,400	0	40.0	30.0	13.5	0.0	83.5
PL	30	Lab	L1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	28	Exam	L2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
PL	42	Exam	L3	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
					#Positive CC evaluations	26	25	22	0	67,200	44,400	29,200	0					
					Efectiveness	65.0	62.5	55.0	0.0									

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	70						70.6	44.5	88.5	83.5	85.1	0.0	71.9	77.7
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	7	400	3	4	3	0	6,400	6,600	4,800	0	16.0	16.5	12.0	0.0	44.5
A	100	Exam	E3	7	400	6	6	6	0	14,400	10,800	10,200	0	36.0	27.0	25.5	0.0	88.5
C3	100	Exam	E4	8	400	8	8	4	0	16,000	12,000	5,400	0	40.0	30.0	13.5	0.0	83.5
PL	30	Lab	L1	27	2,700	19	0	0	24	38,000	0	0	192,000	14.1	0.0	0.0	71.1	85.2
PL	28	Exam	L2	1	100	0	0	1	1	0	0	1,000	6,000	0.0	0.0	10.0	60.0	70.0
PL	42	Exam	L3	2	200	2	1	2	2	4,000	1,000	2,000	12,000	20.0	5.0	10.0	60.0	95.0
T	50	Assig	T1	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
T	50	Assig	T2	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
					#Positive CC evaluations	47	26	25	27	109,200	45,400	32,200	210,000					
					Efectiveness	67.1	60.5	58.1	90.0									

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						70.6	44.5	88.5	83.5	85.1	45.0	75.3	75.3
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	6	190	5	3	5	0	6,400	3,000	4,800	0	33.7	15.8	25.3	0.0	74.7
C2	100	Exam	E2	7	400	3	4	3	0	6,400	6,600	4,800	0	16.0	16.5	12.0	0.0	44.5
A	100	Exam	E3	7	400	6	6	6	0	14,400	10,800	10,200	0	36.0	27.0	25.5	0.0	88.5
C3	100	Exam	E4	8	400	8	8	4	0	16,000	12,000	5,400	0	40.0	30.0	13.5	0.0	83.5
PL	30	Lab	L1	27	2,700	19	0	0	24	38,000	0	0	192,000	14.1	0.0	0.0	71.1	85.2
PL	28	Exam	L2	1	100	0	0	1	1	0	0	1,000	6,000	0.0	0.0	10.0	60.0	70.0
PL	42	Exam	L3	2	200	2	1	2	2	4,000	1,000	2,000	12,000	20.0	5.0	10.0	60.0	95.0
T	50	Assig	T1	1	100	1	0	0	1	3,000	0	0	3,000	30.0	0.0	0.0	30.0	60.0
T	50	Assig	T2	1	100	1	0	0	0	3,000	0	0	0	30.0	0.0	0.0	0.0	30.0
					#Positive CC evaluations	49	26	25	28	115,200	45,400	32,200	213,000					
					Efectiveness	68.1	57.8	55.6	87.5									

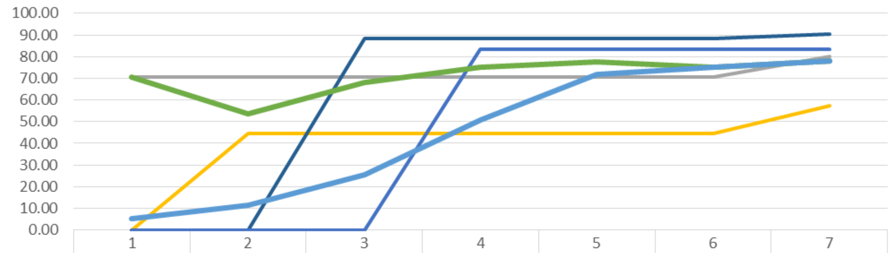
										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	81						80.2	57.3	90.4	83.5	85.1	45.0	78.1	78.1
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_2)$	$g(CC_3)$	$g(CC_4)$	$g(A_t)$
C1	10	Test	P1	12	1,200	4	4	4	0	24,000	12,000	4,000	0	20.0	10.0	3.3	0.0	33.3
C1	90	Exam	E1	10	330	9	7	9	0	12,000	7,200	9,000	0	36.4	21.8	27.3	0.0	85.5
C2	100	Exam	E2	10	520	6	7	6	0	11,200	10,200	8,400	0	21.5	19.6	16.2	0.0	57.3
A	100	Exam	E3	9	480	8	8	8	0	17,600	13,200	12,600	0	36.7	27.5	26.3	0.0	90.4
C3	100	Exam	E4	8	400	8	8	4	0	16,000	12,000	5,400	0	40.0	30.0	13.5	0.0	83.5
PL	30	Lab	L1	27	2,700	19	0	0	24	38,000	0	0	192,000	14.1	0.0	0.0	71.1	85.2
PL	28	Exam	L2	1	100	0	0	1	1	0	0	1,000	6,000	0.0	0.0	10.0	60.0	70.0
PL	42	Exam	L3	2	200	2	1	2	2	4,000	1,000	2,000	12,000	20.0	5.0	10.0	60.0	95.0
T	50	Assig	T1	1	100	1	0	0	1	3,000	0	0	3,000	30.0	0.0	0.0	30.0	60.0
T	50	Assig	T2	1	100	1	0	0	0	3,000	0	0	0	30.0	0.0	0.0	0.0	30.0
					#Positive CC evaluations	58	35	34	28	128,800	55,600	42,400	213,000					
					Efectiveness	71.6	64.8	63.0	87.5									

6.5.4 Evolution graphics

Next graphics show the evolution of the different studied concepts along the seven moments of evaluation included within the backlog of activities.

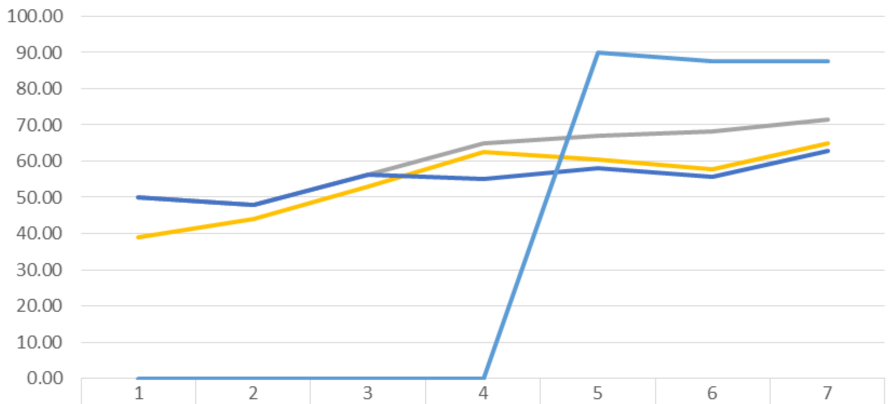
Current grade graphic shows the grade of the four topics and the final grade. We can observe as the contributive final grade is a progression along the course which represent the “quantity of grade” achieve so far.

Current grade



	1	2	3	4	5	6	7
C1	70.60	70.60	70.60	70.60	70.60	70.60	80.24
C2	0.00	44.50	44.50	44.50	44.50	44.50	57.31
A	0.00	0.00	88.50	88.50	88.50	88.50	90.42
C3	0.00	0.00	0.00	83.50	83.50	83.50	83.50
FG	70.60	53.50	68.20	75.00	77.72	75.26	78.11
CFG	5.29	11.64	25.57	50.62	71.89	75.26	78.11

Effectiveness



	1	2	3	4	5	6	7
Ef1	50.00	48.00	56.25	65.00	67.14	68.06	71.60
Ef2	38.89	44.00	53.13	62.50	60.47	57.78	64.81
Ef3	50.00	48.00	56.25	55.00	58.14	55.56	62.96
Ef4	0.00	0.00	0.00	0.00	90.00	87.50	87.50

This graph shows the effectiveness of positive evaluation in relation to the total of activities evaluated in each cluster of competences. Ef4 is the cluster referred to competence M24 Making use of aids and tools and only applied from the MoEv 5 when the lab sessions and practices activities appears in the backlog.

Next two graphics are histograms about the grade of achievement of competence clusters.

Given that the sum of the weights of each competence cluster does not have a distribution of 100%, the grades of achievement are not comparable between them.

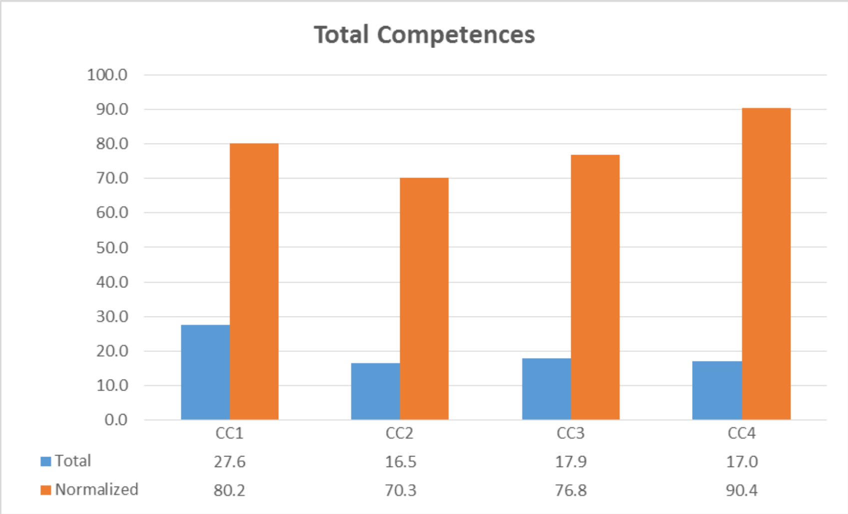
	C1	C2	A	C3	PL	T
g(CC1)	34.73	36.36	21.54	36.67	12.62	30.00
g(CC2)	20.64	21.82	19.62	27.50	2.10	0.00
g(CC3)	24.88	27.27	16.15	26.25	7.00	0.00
g(CC4)	0.00	0.00	0.00	0.00	63.33	15.00

To normalize the computed grade of achievement in a scale 0%-100% we calculate the maximum grade that a student could obtain if all the activities are evaluated with a positive grade.

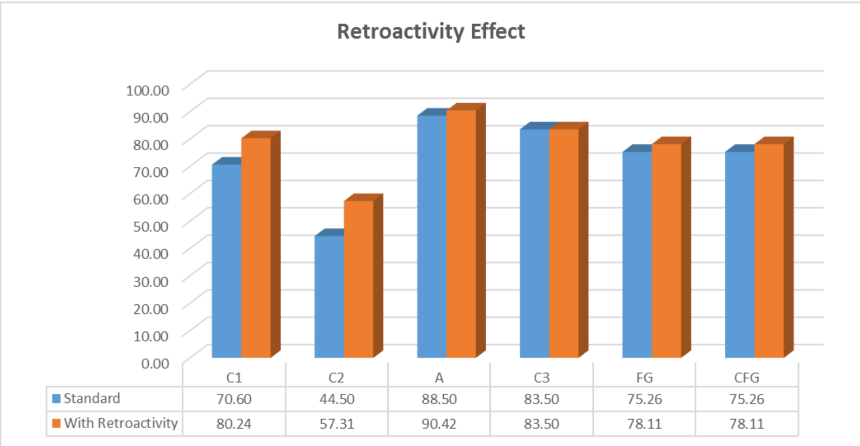
	C1	C2	A	C3	PL	T
g(CC1)	82.68	90.91	53.85	91.67	63.11	100.00
g(CC2)	68.79	72.73	65.38	91.67	30.00	0.00
g(CC3)	88.85	90.91	53.85	87.50	100.00	0.00
g(CC4)	0.00	0.00	0.00	0.00	95.96	50.00

We maintain a pATC cuboid with the maximum grade of execution for each student given that the number or type of activities executed could vary from between them. For example, retroactivity produce different number and type of vectors for each student or some students could execute personal sets of reinforce activities.

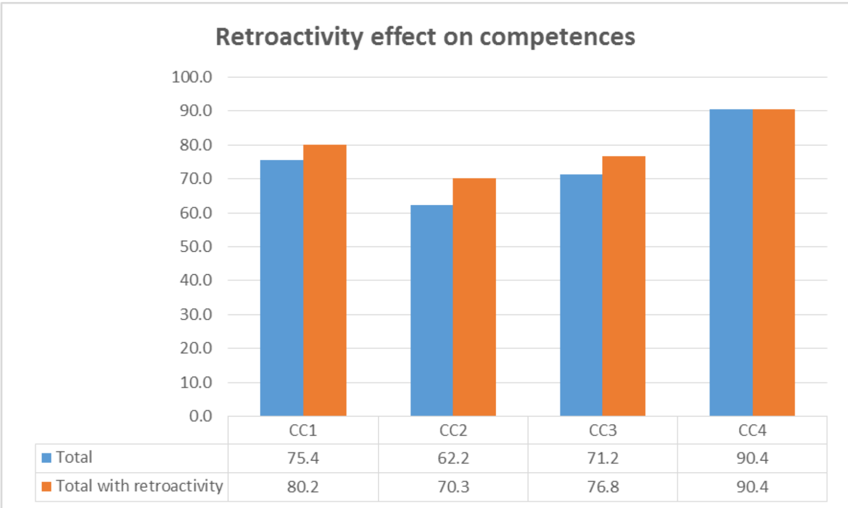
We also can compute the overall grade of achievement of each competence cluster applying the weights of each topic to average the competences.



Next table shows the effect of retroactivity on distinct topics and final grades.



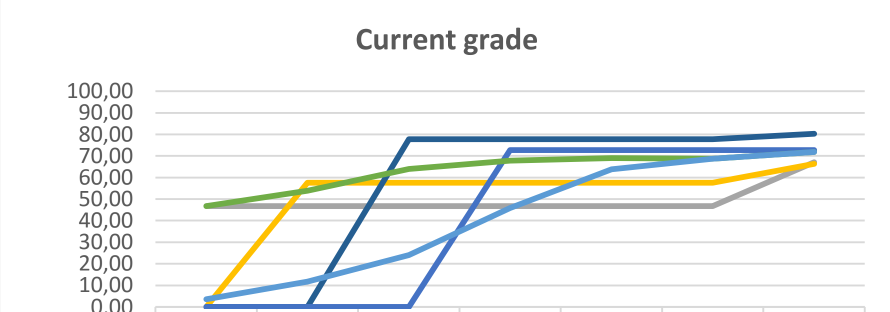
And the effect of retroactivity on competences achievement



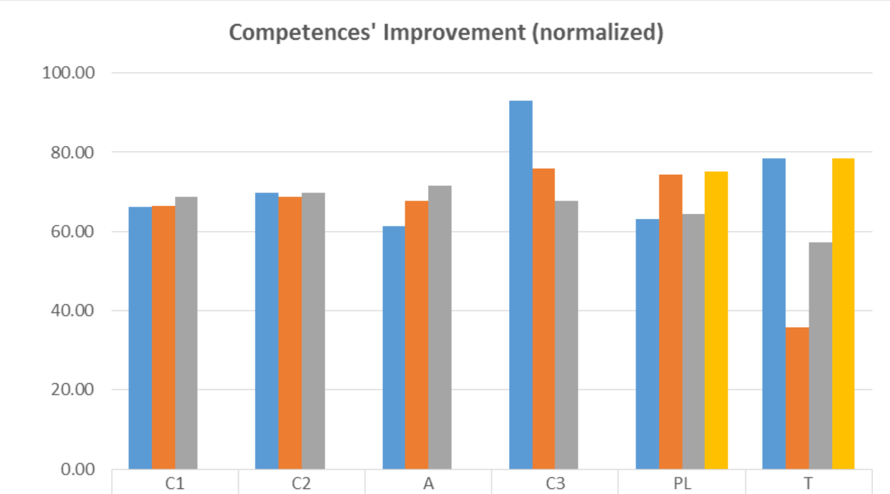
6.5.5 Results on total sample

Given that the ATC cuboids method is an additive system, we could join the activities from all the student in one backlog obtaining a group ATC which allow us to study the general evolution of the group form the point of view of the topics or competences.

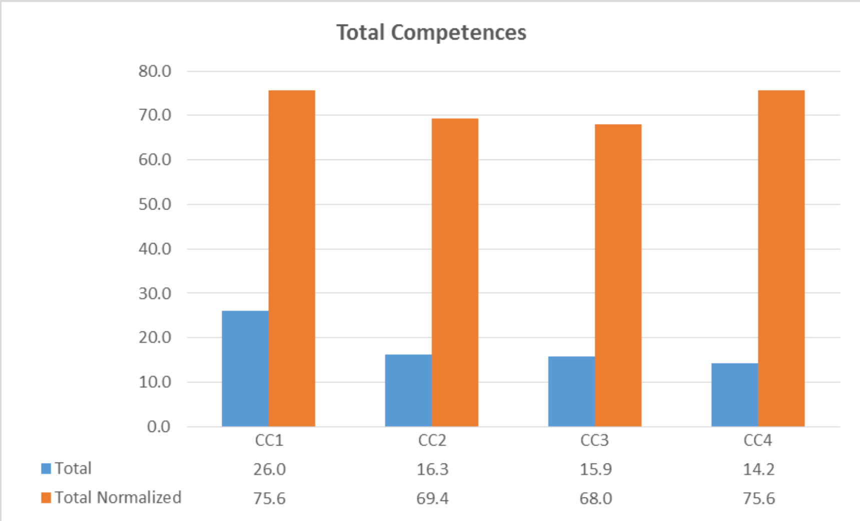
We reproduce here some of the graphics about the group:

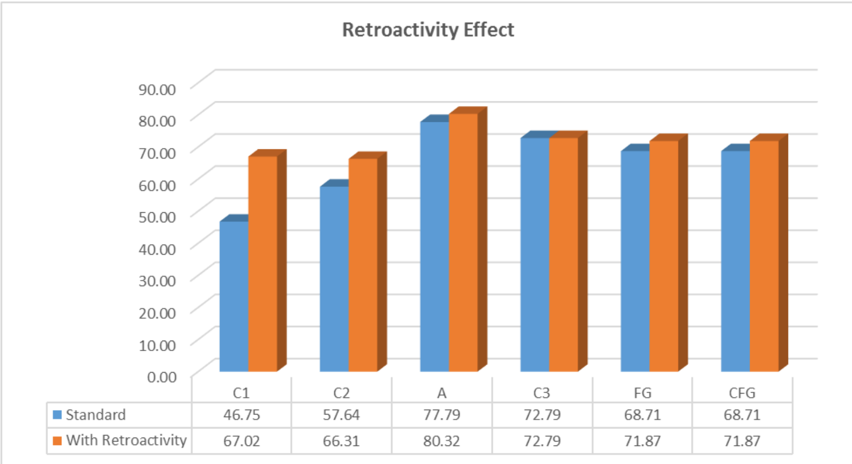


	1	2	3	4	5	6	7
C1	46,75	46,75	46,75	46,75	46,75	46,75	67,02
C2	0,00	57,64	57,64	57,64	57,64	57,64	66,31
A	0,00	0,00	77,79	77,79	77,79	77,79	80,32
C3	0,00	0,00	0,00	72,79	72,79	72,79	72,79
FG	46,75	53,89	63,92	67,86	68,96	68,71	71,87
CFG	3,51	11,72	23,97	45,81	63,78	68,71	71,87

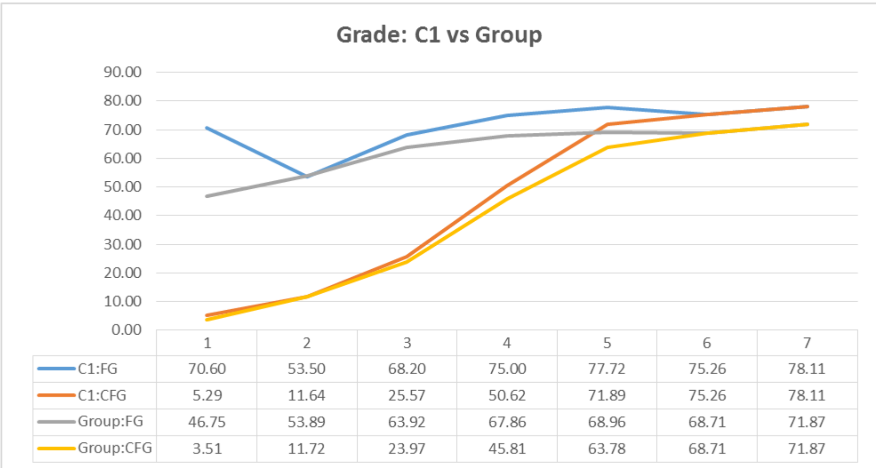


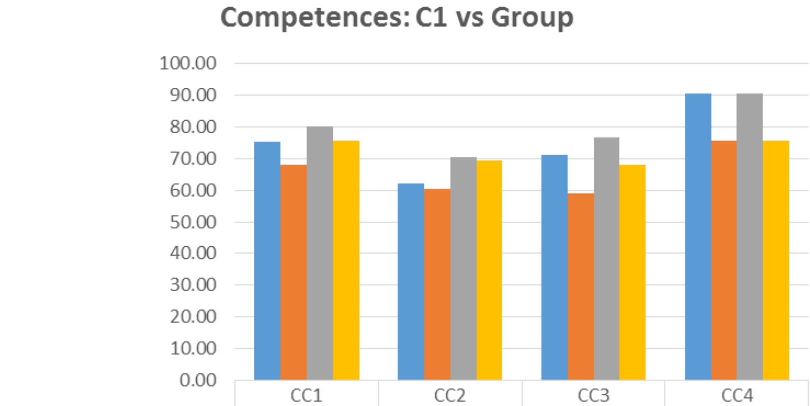
	C1	C2	A	C3	PL	T
g(CC1)	66.20	69.70	61.36	93.04	63.02	78.57
g(CC2)	66.47	68.83	67.61	75.95	74.29	35.71
g(CC3)	68.82	69.70	71.59	67.72	64.29	57.14
g(CC4)	0.00	0.00	0.00	0.00	75.16	78.57





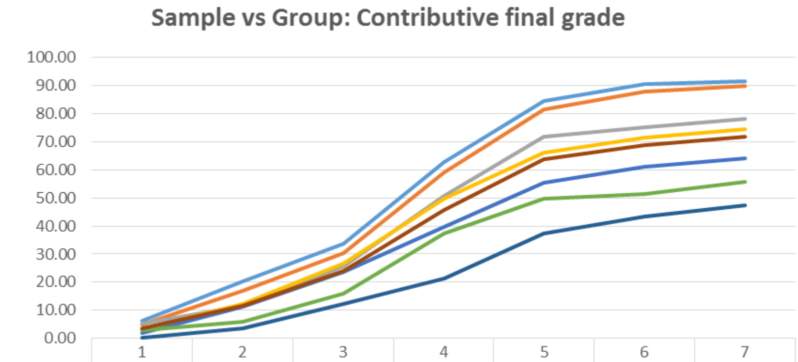
And a comparative between C1 vs group about grades and competences achievement



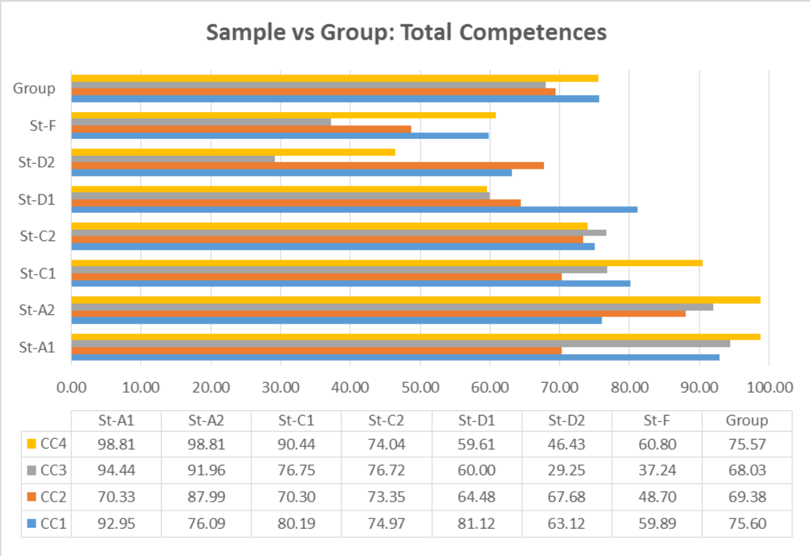


	CC1	CC2	CC3	CC4
C1	75.43	62.19	71.18	90.44
Group	68.02	60.36	58.93	75.57
C1 with Retroactivity	80.19	70.30	76.75	90.44
Group with Retroactivity	75.6	69.4	68.0	75.6

And we also could compare all the students included in the sample with the average results of the total sample:



	1	2	3	4	5	6	7
St-A1	6.18	20.43	33.59	62.69	84.55	90.55	91.44
St-A2	5.06	16.95	30.42	59.07	81.53	87.90	89.88
St-C1	5.29	11.64	25.57	50.62	71.89	75.26	78.11
St-C2	3.15	12.27	26.60	49.85	66.04	71.29	74.40
St-D1	1.80	11.14	23.58	39.63	55.44	61.06	64.11
St-D2	2.81	5.94	15.87	37.32	49.65	51.53	55.87
St-F	0.25	3.67	12.18	21.48	37.39	43.39	47.24
Group	3.51	11.72	23.97	45.81	63.78	68.71	71.87



	St-A1	St-A2	St-C1	St-C2	St-D1	St-D2	St-F	Group
CC4	98.81	98.81	90.44	74.04	59.61	46.43	60.80	75.57
CC3	94.44	91.96	76.75	76.72	60.00	29.25	37.24	68.03
CC2	70.33	87.99	70.30	73.35	64.48	67.68	48.70	69.38
CC1	92.95	76.09	80.19	74.97	81.12	63.12	59.89	75.60

In annex I we reproduce the results for the other students of the sample selected.

6.6 Comparative results

After all the students from the selected sample were re-evaluated, the results obtained by means of the ATC cuboids method and the results of the ETSID evaluations are the following ones:

ATC method

Student	C1	C2	A	C3	PL	T	FG
A1	8.25	10.00	8.35	9.70	90.55	90.55	9.06
A2	6.74	8.35	8.55	9.55	89.82	85.00	8.79
C1	7.06	4.45	8.85	8.35	85.06	45.00	7.53
C2	4.19	6.40	9.10	7.75	64.76	70.00	7.13
D1	2.41	6.55	7.90	5.35	63.22	75.00	6.11
D2	3.74	2.20	6.30	7.15	49.36	25.00	5.15
F1	0.33	2.40	5.40	3.10	63.67	80.00	4.34

ETSID evaluations

Student	C1	C2	A	C3	PL	T	FG
A1	8.00	10.00	8.75	9.75	9.16	7.49	9.18
A2	6.00	8.80	9.00	9.65	9.45	8.30	9.00
C1	7.50	5.00	9.20	8.25	8.49	4.93	7.69
C2	4.00	6.50	9.50	7.50	6.50	6.62	7.09
D1	2.50	6.25	8.25	5.75	5.71	7.40	6.09
D2	3.50	2.50	6.75	6.00	5.03	2.73	4.94
F1	1.50	2.00	6.20	2.75	5.76	8.22	4.26

And after we apply the retroactivity:

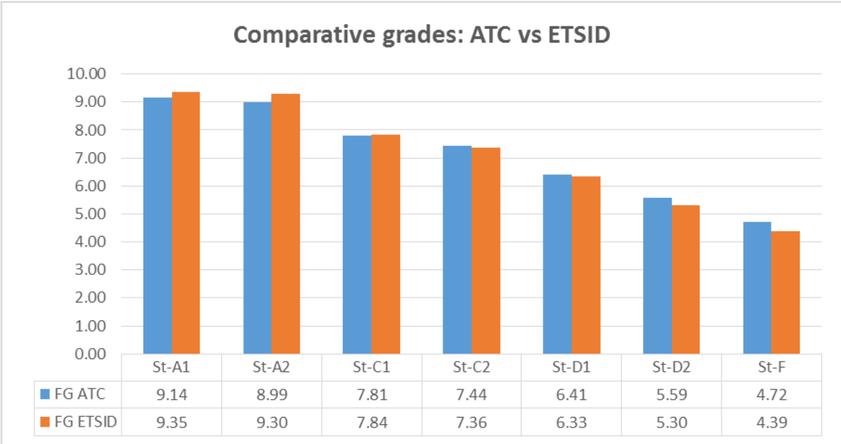
ATC method with retroactivity

Student	C1	C2	A	C3	PL	T	FG
A1	8.85	10.00	8.63	9.70	9.14	9.14	9.14
A2	7.95	8.73	8.88	9.55	8.98	8.50	8.99
C1	8.02	5.73	9.04	8.35	8.51	4.50	7.81
C2	6.45	7.23	9.25	7.75	6.48	7.00	7.44
D1	5.38	7.13	7.90	5.35	6.32	7.50	6.41
D2	6.12	4.00	6.30	7.15	4.94	2.50	5.59
F1	4.15	3.09	5.40	3.10	6.37	8.00	4.72

ETSID evaluations with retroactivity

Student	C1	C2	A	C3	PL	T	FG
A1	9.00	10.00	9.38	9.75	9.16	7.49	9.35
A2	7.83	9.40	9.50	9.65	9.45	8.30	9.30
C1	8.75	5.00	9.54	8.25	8.49	4.93	7.84
C2	6.58	7.00	9.50	7.50	6.50	6.62	7.36
D1	4.58	6.88	8.25	5.75	5.71	7.40	6.33
D2	3.50	5.00	6.75	6.00	5.03	2.73	5.30
F1	2.00	2.67	6.20	2.75	5.76	8.22	4.39

Results are very similar between them. The retroactivity ATC, in general, obtains better grade increases from the point of view of the student, although it depends on the design of the rules of retroactivity and the value of the experience accelerator. In the present study, retroactivity rules have been designed to completely parallel the procedures applied at ETSID.



On the other hand, the weights included in the master ATC has been selected to match with the weights used at ETSID to avoid differences between results which are not due to the assessment procedure. Additionally, as we already have mentioned, at ETSID it is applied a concept of retroactivity based on including questions in some topics exams referring to previous topics in order to increase their grades if some conditions are met.

The choice of the weights of the master ATC can be performed in such a way that they can reflect the scoring strategy designed by the person in charge of the subject.

Weights assigned in a task are distributed between competencies, or cluster of competencies, in base 100 in order to get an individual grade of the activity in the range of grades established.

The weights assigned to individual tasks within one or more topics, or the set of activities which compound a moment of evaluation, can be defined by any magnitude. Thus we can highlight the importance of some activities over others and the relevancy of its contribution to the grade of the moment of evaluation. This way, we can always introduce a lot of activities in the evaluation process where contribution to the final grade is the criteria keynote. For example, solving problems outside the class may have assigned a very low weight in such a way that even though there will be many activities, its weight is limited to 10% of the grade and they are rewarded as a contribution to final grade.

The weights of the topics within the overall process must have a 100 distribution to get a grade in the desired range.

ATC process is additive therefore it admits at any times to add execution of new activities. This way, the retroactivity generates “virtual executions” as a way of improve the grade of previous moments of evaluation

The main difference between both methods is the procedure to assess an activity through binary indicator about some predefined competences with produce vector grades instead of scalar grades. This characteristic allows us a more detailed analysis about the progression of the students.

7 Dynamic assignments

7.1 Introduction

The use of ATC cuboids change the scalar nature of the evaluation's results by a numerical matrix which establish a strong relationship between the concept of activity, topic and competence generating a greater volume of information that allows us to make a more specific diagnosis of the students' performance.

Major number of activities increases the amount of information and the process complexity. Thus, an automation of the information processing becomes to be necessary. Also, the use of techniques of e-learning and self-evaluation are elements that help to increase the number of activities and its evaluation of an automated way.

In this chapter we present a conceptual model to register the ATC cuboids information. The dynamic analysis of this information will allow us to model assignable workloads to students in order to guide them towards the achievement of individual and group objectives.

7.2 Objective ATC

An objective ATC cuboid, hereinafter oATC, is a cuboid with the same structure as a personal ATC, hereinafter pATC, which contains a scoring distribution according to a pre-established final target. Since the punctuations of a pATC change in a contributive sequence as it is being fueled with new execution of evaluated activities, an oATC also changes with the number of activities, but maintaining an established objective profile.

From the point of view of calculus, it implies that for every activity execution we have to introduce a vector evaluation into the oATC according to the established objective profile and to evolve the oATC.

Another way of setting goals is to draw profiles or histograms for competence's development according to different objective level and compare the pATC. Then, oATC cuboids that evolve in parallel to the number of activities are suitable to set and follow individualized goals since not all students will run the same activities or the same number of them. Competence profiles are useful to measure group's objectives.

7.3 Master ATC

Master ATC cuboid, hereinafter mATC, contains the score model for binary assessment of activities' execution. It is divided into thematic units or topics covering an entire course subject. These topics will be the main elements of the summative evaluations or main moments of evaluation. Each topic has a weight that indicates its relevance within the subject. The sum of the weights of all the topics is 100.

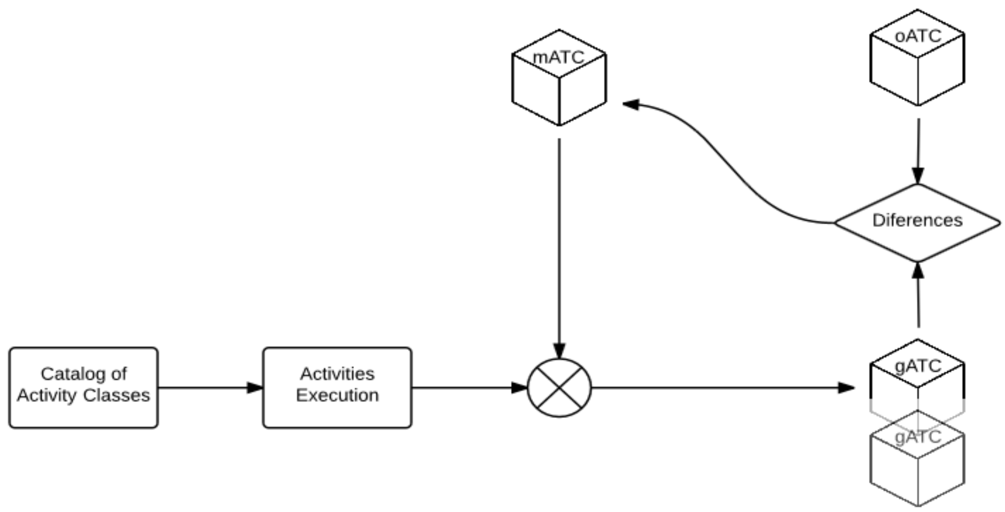
Each topic is subdivided into activity classes, or types, whose execution will be evaluated and which make up formative tasks that individually contribute in a continuous way to obtaining a final grade. Each of these kinds of activities, as we have already seen in previous chapters, also has a specific weight distribution within a topic in order to mark the relevance of the activity within the topic.

Finally, each activity class is subdivided into subclasses due to different instances of similar nature activities that could have a different impact on the competence's development. And again, each subclass is also assigned a weight within the class to remark the relevance of the activity subclass within the activity class.

Therefore, when an activity is evaluated, a search takes place in the mATC for topic, class and subclass and the weight's vector is extracted. The product of the components of the binary assessment vector and master vector produces one contributive scalar for each of the competences evaluated in the model.

Thus, it is really important to get a mATC which represent in a true way the contribution of each activity execution to the final evaluation of a student. The selection of weights for each topic is relatively simple taking into account the relevance of the topic within the subject and the effort that has been planned to spend with it. Choosing weights for classes and subclasses of activities is more complex because there is a broad variation in the complexity of them. The composition of the cuboid is also sensitive to the type and number of activities planned for a course.

A possible method to get a mATC consists in making an iterative approximation based on traditional assessments on a set of activities. The working method could be as follows:



- Create a mATC based on the initial experience and the probable impact of each activity class on the basic competences.
- Turn into individual activities the previously evaluated work. Thus, a written exam will generate an activity by each question. Laboratories generate an activity by each of the issues practiced in the laboratory and so on.
- Generate a table of activities and reassess with the binary assessment method.
- Categorize activities in classes and subclasses.
- Apply the mATC to the sequence of activities.
- Compare the results obtained with the oATC and test its validity.
- Based on results, make the necessary adjustments to the mATC weights.

- Recalculate the model with the new mATC.
- Follow the procedure iteratively until an acceptable validity of the model.

In the same way, we could check the results obtained comparing with the aggregate ATC for the entire group, gATC.

7.4 The activity bank

The activity bank is the repository that contains the reference to all executable activities which are the elements that fuel the binary assessment model based on ATC cuboids.

The activities, covering a course programme, are from a very diverse nature and, in general, it will not be possible to have a bank of activities that contains all of them by itself. What is relevant from an operational point of view is to have a model of references that permits to obtain a link to access the activity and, on the other hand, to be able to characterize the activity so that it is usable by the model.

Currently, some authors develop theory on e-learning distributable objects through the use of web services.

According Vossen (2003), content consumed by learners and created by authors is commonly handled, stored, and exchanged in units of learning objects (LOs). Basically, LOs are units of study, exercise, or practice that can be consumed in a single session, and they represent reusable granules that can be authored independently of the delivery medium and be accessed dynamically, e.g., over the Web. Additionally, learning objects can be stored in a database and are typically broken down into a collection of attributes.

Again, Vossen (2002), says that e-learning consists of a multiplicity of complex activities such as content authoring or learner tracking and administration which interact with resources (including people such as learners and authors), with one another (some activities trigger others), and with the outside world (such as existing software systems) in a predefined way. And some e-learning platforms and systems have been developed and commercialized based on client-server, on peer-to-peer, or, more recently, on Web service architectures.

According Downes (2000) and Fischer (2001), learning objects are the core concept in an approach to learning content in which content is broken down into bite size chunks. These chunks can be reused, created and maintained independently, also pulled apart and stuck together like so many Legos.

Vossen establishes some aggrupation for learning objects in classes. A class could be comprised by a collection or sequence of learning objects according to a class map. This aggrupation would roughly correspond to a class in a university that extends over several sessions or class meetings. In reference to the composition of more complex learning units, he affirm that a course program comprised of several classes (such as one offered in a virtual university) would need a larger collection of learning objects, potentially from a variety of sources and grouped into several classes.

In this work we do a similar approach from the point of view of the evaluation process. The implementation of activities is the object that feeds the model. The activities are objects designed and proposed by the teacher, or there are objects designed by others ones and consumed as a services.

From a meta-conceptual point of view, the activity bank consists of the following elements:

- A link to the activity to access and execute it. In other words, access to some system where the activity can be executed. This system can be a classroom, a laboratory or certain software.
- A set of data associated with the activity that characterize it within the model (course, topic, class and subclass of activity) which means that it will have a vector of weights assigned to push the activity into the evaluation process.
- A "driver" that allows us to translate the outcomes of the activity execution in a binary vector to feed the ATC model.

Thus, the activity bank is a meta-concept of activities provisioning to fuel the ATC model. It is a necessary instrument to implement algorithms of dynamic assignments of activities.

From the point of view of the activity site and the location from which the activity is execute, it should be established some criteria in relation to its validity as an element of learning and evaluation. Thus, we can distinguish two different environments: controlled and uncontrolled.

- A controlled environment which allows us to guarantee the authorship of the activities' execution. For example, attending lectures, written exams and laboratory practices are activities to be executed in controlled environments.
- A non-controlled environment, on the contrary, is that not allows to guaranteeing the authorship of the activities' execution. Electronic methods of identification only guarantee that the subject that emits an activity execution is the identified but not necessarily the executor. In this category you can include activities of e-learning, assignments to do in house, MOOCs, etc.

For example, McMurtry (2001) cites a survey from *Who's Who Among American High School Students* which reported that out of 3,123 students, 80 percent of them "admitted to cheating on an exam, a 10-point increase since the question was first asked 15 years ago". Furthermore, 50 percent of them "did not believe cheating was necessarily wrong," and 95 percent of those who had cheated "said they had never been caught" (Kleiner and Lord 1999).

According Eplion (2007) technology and the Internet can both facilitate cheating. Students taking online exams can benefit from collaborating with others, access to resources, and the ability to have someone take an assessment on their behalf. A study to determine whether cheating is more prevalent in online classes, as opposed to on-campus, shows that the level of cheating in an online course was consistent with that of an on-campus class during a single semester (Grijalva, Nowell, & Kerkvliet, 2006).

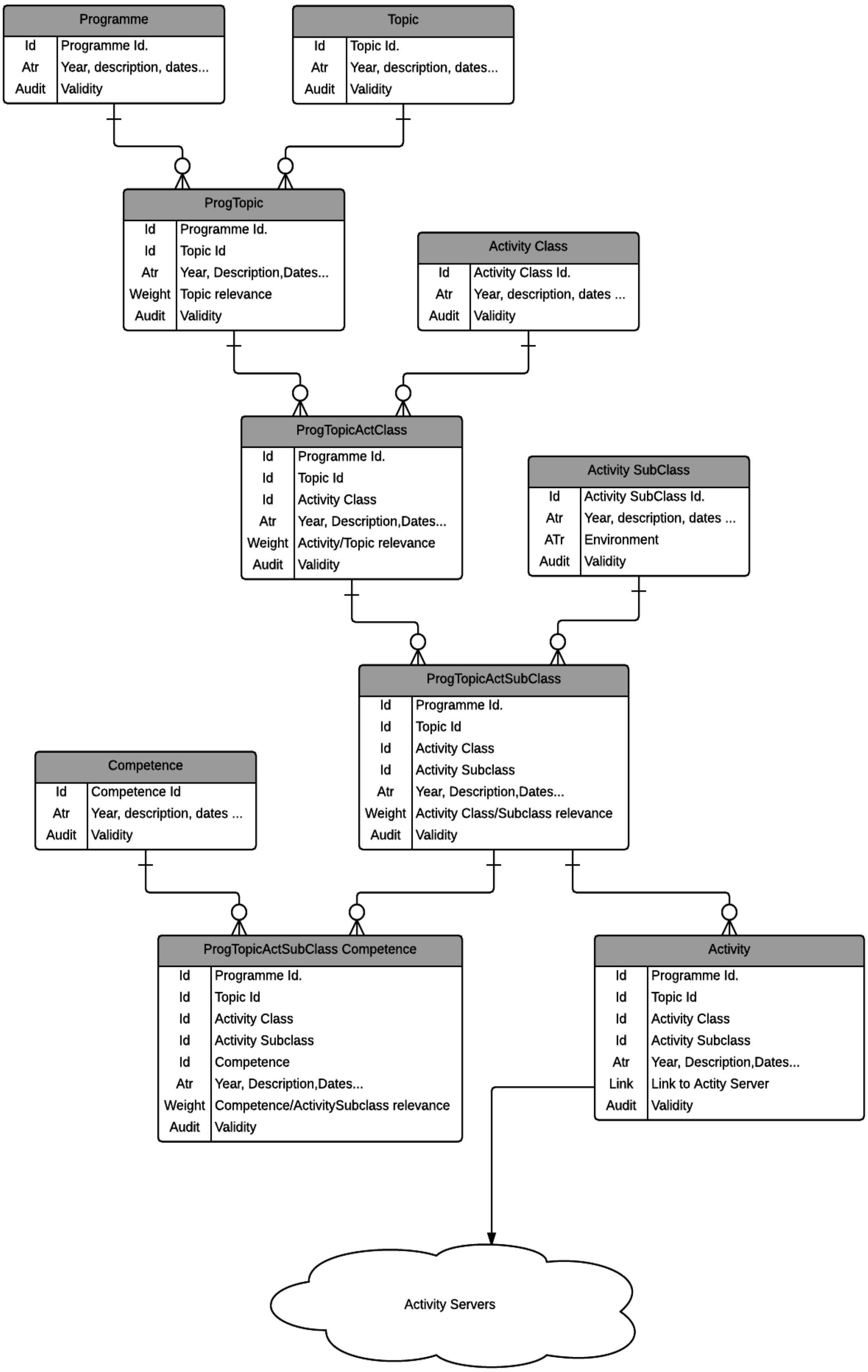
Some services like **Proctor U** uses live online proctoring service with three step authentication process: Webcam, Monitor student's computer screen in real time and multifactor process.

Anyway, as the causes of cheating are really difficult to prevent, one activity executed in a non-controlled environment will have a very small contributory impact with regard to the same activity executed in a controlled environment. Nevertheless, we must highlight that, independently of the context where it is executed, all activity is an activity formative and, as such, it must have its contribution. The execution's guarantee is something beforehand supposed.

Some strategies applied this year to the first year students have been to make assignments to work outside the classroom supplemented with a classroom test about the execution of the same assignments in a very short period of time. This strategy increases the guarantees on the authorship of the executions. We could implement this strategy applying an accelerator on the activities executed out of the class if the onsite test is positive.

The concept of activity bank that we have developed here is an abstraction since it is a complex environment. For bank activity we will understand an accessible set of activities identified and characterized from an academic point of view, its relationship with the topics of the subject, and its impact on the development of the competences. This set of activities is of very diverse nature and accessibility. We include in this concept so much accessible activities by a computerized system (e-learning courses, MOOCs, laboratory software, etc.) as not accessible by computer systems (classes, activities of textbooks, work in group, written tests, etc.). The concept refers to the accessibility of a set of activities and its metadata. Once assigned an activity to a student, it is supposed that it will be a physical access to such activity, from a computer to a sheet of written paper.

In the attached figure we represent a conceptual model that allows us to register the identifiers of the activities so that they could be assigned to the students by means of the use of assignment algorithms. We do not try to draw a complete design of the data structure, given that many other attributes should be considered.



Programme
Id Programme Id.
Atr Year, description, dates...
Audit Validity
Topic
Id Topic Id.
Atr Year, description, dates...
Audit Validity
ProgTopic
Id Programme Id.
Id Topic Id
Atr Year, Description,Dates...
Weight Topic relevance
Audit Validity
Activity Class
Id Activity Class Id.
Atr Year, description, dates ...
Audit Validity
ProgTopicActClass
Id Programme Id.
Id Topic Id
Id Activity Class
Atr Year, Description,Dates...
Weight Activity/Topic relevance
Audit Validity
Activity SubClass
Id Activity SubClass Id.
Atr Year, description, dates ...
ATr Environment
Audit Validity
ProgTopicActSubClass
Id Programme Id.
Id Topic Id
Id Activity Class
Id Activity Subclass
Atr Year, Description,Dates...
Weight Activity Class/Subclass relevance
Audit Validity
Competence
Id Competence Id
Atr Year, description, dates ...
Audit Validity
ProgTopicActSubClass Competence
Id Programme Id.
Id Topic Id
Id Activity Class
Id Activity Subclass
Id Competence
Atr Year, Description,Dates...
Weight Competence/ActivitySubclass relevance
Audit Validity
Activity
Id Programme Id.
Id Topic Id
Id Activity Class
Id Activity Subclass
Atr Year, Description,Dates...
Link Link to Actity Server
Audit Validity
Activity Servers

Thus, a program (programme) is composed of various topics (topics) that define the content of a course (ProgTopic). Different kinds of activities (ActivityClass) define all executable activities for a given topic (ProgTopicActClass), which is subdivided into subclasses of activities according to their impact on the development of competencies (ProgTopicActSubClass). Each of these subclasses has defined impacts (ProgTopicActSubClass Competence) on individual skills that are evaluated during the course (skills). In addition, each of these subclasses consists of one activity set (Activity) which have a link to access and identify the activity in the Bank's activities.

All data entities should identify the academic year (year), as well as validity (validity) data that make up a set of coherent information. An implementable real model is more complex than outlined here, where the idea is to show the concept of identification and registration of the Bank's activities.

The content of this data model should be set at the beginning of the year. It must be kept constant throughout the entire course because from this structure is obtained the mATC.

The Bank's activities is the core on which it is based the entire system given the continuous evaluation process based on the implementation of activities and these are to be assigned previously to the students so they can run them and register their results.

7.5 The activity backlog

The activities assignment refers to the process of selecting a set of activities that one student should execute and feed back into the continuous evaluation process.

A data structure should be designed to register the student's activity assignments. This data structure is *the activity backlog* and we are going to design it as a multidimensional model that is most useful for analytical studies.

To characterize the assignment process we introduce six dimensions:

- dimActivity

It refers to the subclass of assigned activity. It is already a de-normalization of the model of activities and implies the hierarchy activity-topic-year.
Main attributes are:

- A non-significant key register.
- Activity hierarchy: programme, topic, activity class and subclass and their weights.
- Competences used in the process and their associated weights.
- Audit attributes for validity.
- Other attributes considered of interest by the academic institution.

- dimDate

It refers to the dates and times in which it happens the different events related to the assignment and execution of an activity.
It has the typical structure of the date dimensions containing dates, times, hierarchies regarding periods of time like trimester, summer, extraordinary period and so on, that are considered of interest by the academic institution.
We will use different attributes date for which we will reference dimDate dimension in role playing mode (load once and use as a view for different contexts). Specifically: for assignment, execution and simulation.

- dimStudent

It refers to the students identification to whom the activity is assigned and their hierarchies (course, group and many other attributes)

- dimAssigner

Responsible for the allocation of activities to a student, who may be the subject teacher or anyone else of the academic institution devoted to these tasks and some hierarchies.

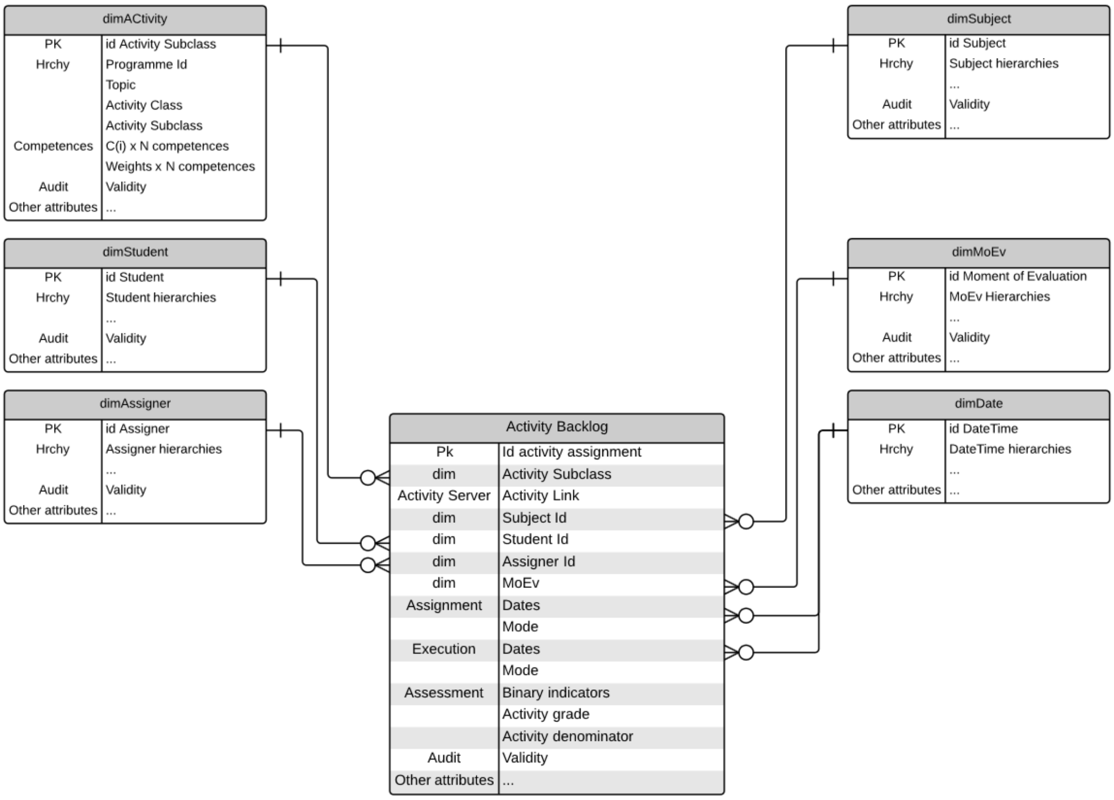
- dimSubject

Subject which activities are assigned for and its hierarchies (course, plan, and other descriptive attributes).

- dimMoEv

  It refers to the moment of evaluation in which the activity is executed. The moment of evaluation is important in order to generate subject grades and implement the retroactivity process.

A schema of the backlog model could be:



The activity backlog is implemented as a fact table containing:

- An identification of the activity assignment (non-significant).
- Dimensions.
- Assignment
  - Date of assignment.
  - Assignment mode (standard, handy, algorithm, personal, simulation).

- Execution
    - Scheduled interval of execution.
    - Date of execution.
    - Execution mode (standard, retroactivity, accelerator, simulation).
- Binary evaluation of competences (achievements)
- Activity grade
- Activity denominator (contribution to pATCs)

Later, in this chapter, we will study the assignment and execution modes.

7.6 ATC data structures

ATC cuboids require a data structure for storage which provides further analytical studies. ATC cuboids are calculated from the activity backlog aggregating binary assessment vectors for the same student and activity class.

From the activity backlog we could obtain the ATC structures which include the values after the execution of each assigned activity, so it is possible to build an analytical study of its evolution in the timeline.

As the structure contain a large quantity of rows, a row set for each activity execution, we could extract the current status of the ATCs (snapshot) for example, at the end of each moment of evaluation maintaining only the last one.

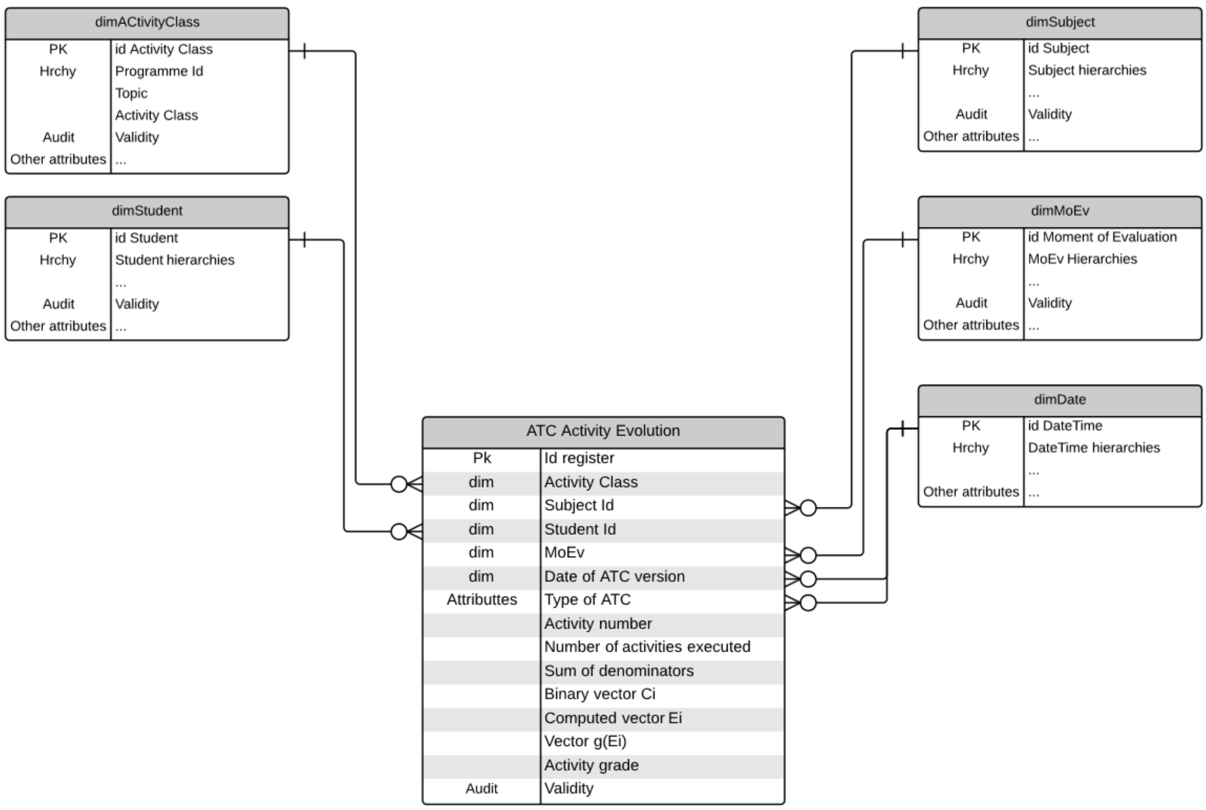
The personal ATC Activity Evolution fact table contains the following attributes:

- A non-significant identifier
- Dimensions
    - dimStudent
    - dimActivityClass (a view from dimActivity without subclass attribute)
    - dimSubject or topic

- dimMoEv
- dimDateCurrentATC

- Number of activity executed
- Type of ATC (pATC. oATC or sATC)
- Number of activities within the activity class
- Sum of denominators within the activity class
- Binary assessment vector (SCC_i)
- Computed assessment vectors ($wSCC_i$)
- Grade vector $g(CC_i)$
- Activity grade

The fact table granularity is a row for each Program-Topic-Activity Class and for each student and activity execution.



We could add a row within each ATC containing the sum of the columns SCC_i and $wSCC_i$.

From this structure we could calculate the contributive and the current grade because we have the necessary components to do it.

To draw the histograms of achievement of competences, as we have seen in Chapter 6, it is necessary to normalize the values obtained in pATC in relation to the values obtained in the case of maximum performance. To do this, we could include a second set of columns SCC_i, $wSCC_i$ and $g(CC_i)$ assuming that all the activities are executed with 100% of effectivity. This way, in the same structure we could dispose of this data.

We could consider three types of ATC cuboids within the aforementioned data structures:

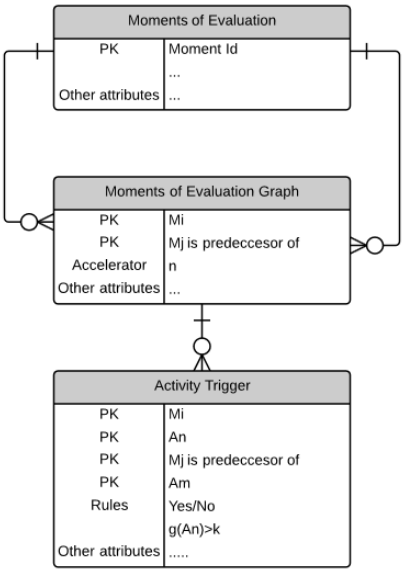
- Personal ATC, pATC, which contains the computed evolution of the continuous assessment process according the activities executed by students.
- Objective ATC, oATC, which contains the objective level for each student. Remember that the objective depends on the number of executed activities. Thus, the objective ATC is could be different for each individual student.
- Simulated ATC, sATC, which contains the probable evolution of a given pATC after the execution of a set of proposed activities within a minimum level of success.

7.7 Retroactivity

A moment of evaluation is an identifier of a group or set of activities. They are sorted over time shaping a succession of control points about the continuous assessment process. Some of these control points could be marked as summative assessment milestones.

As we have seen in chapter 3, we could draw a directed graph whose nodes are a set of relevant moments of evaluation. Retroactivity could be implemented triggering binary assessment vector from an activity of a moment of evaluation toward one or more predecessor moments maybe if none or some rules are accomplished. Additionally, we could strengthen the effect of retroactivity more than a vector on the same predecessor.

Likewise, starting from a given moment of evaluation, we could reinforce the contributive effect of activity's executions generating n equal binary vectors for each execution ($GIA|_{CAP}$).



A possible data structure to modelling the retroactivity and experience accelerators is shown in the next figure.

- Two moments of evaluation M_i and M_j, $i \neq j$, represent a predecessor relationship between them. The entity Activity Trigger represent a binary vector A_m launched toward the moment M_j when the activity A_n have been executed fulfilling the rule $g(A_n) > k$ for a given k. Additionally, an accelerator n can be applied.

- A relationship M_i, M_j with i=j and the accelerator n is greater than 1, represent an implementation of experience accelerators, that is, when an activity is executed on the moment M_i, then n identically composed binary assessment vectors are introduced in the backlog activities.

7.8 Activities assignment

The activities assignment is the process where the list of activities to execute by the students is defined and loaded into the activities backlog.

From the point of view of the modality in which the assignment is initiated, we could distinguish different assignment methods:

- Standard compulsory assignment

  Standard assignment is usually scheduled by the person in charge of the subject. Normally, this person plans sets of activities to be executed for all the students covering the whole programme of the course. This plan is divided into sets of activities for each topic to be covered. The assignment will be normally taking place on time periods according to the number of programmed moments of evaluation. For every moment of evaluation there will be established experience accelerators which take the value 1 by default. The no-execution of a compulsory activity will produce a null binary vector of evaluation that will have a negative impact on the contributive final grade. Additionally, it is necessary to define the precedence graph between the moments of evaluation which implement the retroactivity effect triggered on the execution of some activities.

- Reinforcement assignment

  Throughout the course, the teacher could offer sets of reinforcement activities which the students could voluntarily assign by themselves. These sets of activities could be offered with experience accelerators greater than 1 triggered on success to encourage its execution.

- Recovery assignment.

  When some students obtain low scores in some moments of evaluation, the responsible of the subject will propose sets of recovery activities that will be assigned to the students to redeem their lacks. Its mode of implementation may be voluntary or mandatory.

- Personal assignment

  It refers to the ability of students to select reinforcement activities on a voluntary basis to improve their scores at any time. It could be create sets of activities of free election associated to the different moments of evaluation.

- Dynamic assignment

  Dynamic assignments by means of algorithms will be provided to allow the selection of sets of adequate activities so that students could reach predetermined objectives.

From the point of view of the purpose of the assignment, we can distinguish two types of processes:

- Assignment to execute
- It refers to the assignment of activities to execute in a compulsory or voluntary way. In the first case it will have a contribution determined by the successful/unsuccessful execution or negative contribution for no-execution. In

the case of voluntary executions, the contribution will take effect only after the execution and may, in some cases, have effect only in the case of successful results to encourage their execution.

- Assignment to simulate

  The assignment for simulation takes place when a set of activities is assigned with the purpose of studying its effect on the final grade of a topic or the subject. Students can execute this simulation voluntarily when they aim to achieve an objective, like passing the subject or obtaining a higher final grade.

  It is also a process that could be executed by the teacher to set improvement targets for a set of students, or certain topics of the subject, even to improve performance in some of the competences.

  The assignment for simulation is created into the activities backlog and its execution is simulated with one or several performance profiles. Simulated executions cause a simulated evolution of the pATC to calculate its final effect.

  When a simulation is accepted, the assignment is marked as definitive and a rollback of the evolution of the pATC is made.

  The execution profile can be set under criterion of the student or the person in charge of the subject and also could be obtained by means of a predictive model.

Once discussed the modalities of activities assignment, the core objective of this model refers to the dynamic assignment of activities based on student performance.

At the beginning of the course there are several tasks that the people in charge of the subject could execute to initialize the ATC model:

- To define the contents of the subject, its division in topics and establish a set of moments of evaluation. Although any execution can be considered as a moment of evaluation, in practice, we will assume a moment of evaluation as a set of activities which suppose a summative evaluation of a topic. It will have a major impact in the topic grade and, therefore, a major contribution to the final grade.
- To define the sets of activities of required execution to make up the participation of students in the course (assistance to classes, laboratory practice, group work, work outside the class, tests, written examinations, etc.).

- To draw the precedence's graph between the moments of evaluation to know the impacts of the retroactivity in the execution of the activities.
- To publish the mATC so that all students know the course plan.
- Build the oATCs that allow the students to know the minimum objectives to be achieved to pass the course or to reach different levels of implementation.

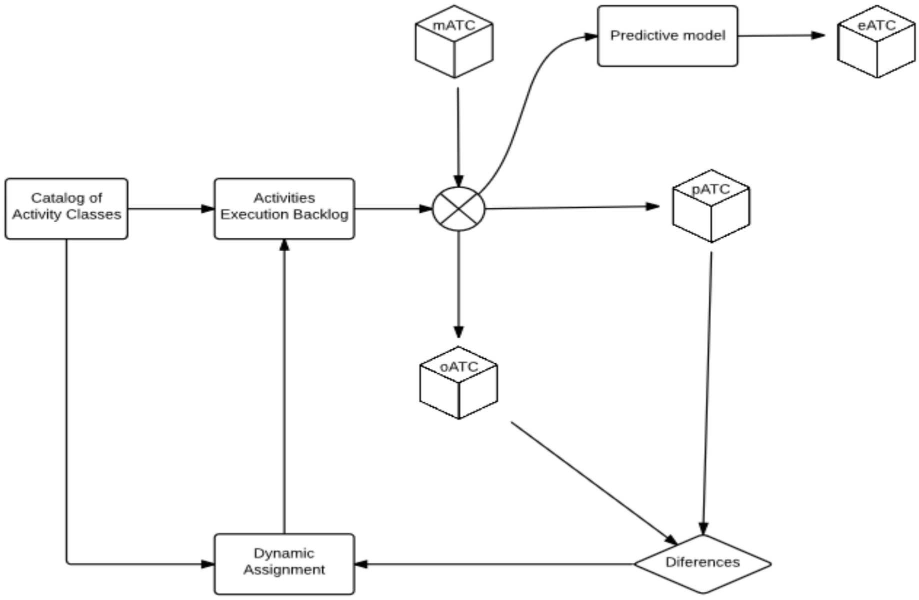
After the starting phase of the course, the publication of the data structures, and the contents of the bank of activities, it makes sense to implement the model of dynamic assignment of activities based on students' performance.

The ATC model compares at determined time intervals the state of the pATC of the students with their respective oATC to detect deviations or to detect the possibility of promoting the objective level to be reached. As a consequence, the system is able to propose a set of activities from the activities bank to be assigned to the student and to guarantee the achievement of the proposed target. The student always follow the execution plan and not a dropout path.

This mode of execution has a number of significant advantages:

- Evenly distributes the workload during the course since it reports at any time the possible final situation of the students.
- It allows to correct deviations of the study plan in advance
- It individualizes the work to realize for every student according to its personal needs like learning ability, previous background, etc.
- It is an inclusive model that respects the individual capacities and modulates the effort to take in certain content to mark the path towards the final objective.

Next figure shows a schema about the process of dynamic assignment of activities:



- Students execute the activities assigned in their backlog of activities
- From the mATC and the binary evaluation of each activity a set of evaluation vectors are built to enter in the pATC
- pATC evolve over time with the contributions of the activities execution
- oATC are recalculated to the levels of objectives achievement after each execution
- A dynamic algorithm compares the composition of pATC against oATC and selects the minimum set of activities that after being executed with a given level of performance ensures the convergence of pATC to oATC.
- The use of a predictive model allows the construction of a cuboid of estimate results based on patterns of execution of activities.

The possible dynamic assignment algorithms are not complex to implement. They can be constructed as of accumulation of contributions from the level of competences of the activities registered in the bank of activities of a certain topic and the use of experience accelerators. It is necessary to limit the number of activities to select to prevent large differences will end in a number of activities to execute not viable. In other words, there can be situations potentially not recoverable.

8 Conclusions and future work

8.1 Conclusions

8.1.1 Introduction

From the various definitions and relevant evaluation techniques in the specialized literature, the concept of evaluation for learning arises from the paradigm of the evaluation of learning. This is done when the objective is to promote the learning process against its technical measurement.

Evaluation for learning seeks to obtain information of your own processes of learning and teaching to stimulate the development of new skills and also to inculcate the reflection on learning in the students compared to systems of measurement for the achievement also measured on the basis of instruments previously designed. It promotes the participation to the entire educational community including students, educators, peers, and professional sectors. It involves a continuous assessment and not in punctual or final moments.

The instruments used in the evaluation for learning are of very diverse nature and they include all types of normal activities in the learning process and all those oriented towards the development of personal and professional competences as discussions, self-assessment, dialogs, working groups, quizzes, etc.

In short, any technical evaluation is going to be implemented around two concepts: the process of measure and the means of implementation. In this sense, the various models claim to measure in some way the knowledge and skills of the students. The use of measure instruments coincides in many of the modalities' views while they differ in their purpose or goal.

From chapters 2 to 7 we have focused mainly on continuous assessment for competences and proposed a new continuous assessment procedure. The instruments of measurement and implantation of the processes of evaluation are the same as those used in any of the other modalities of evaluations.

8.1.2 The method in key concepts

To summarize the assessment method studied along this dissertation, we conclude with a list of keywords and a sequence of implementation.

The keyword list that could define this procedure is:

- Formative assessment
- Development of competences
- Binary assessment and rubrics
- Chain of topics
- Moment of evaluation
- ATC cuboids (Activity, Topic, Competence)
- Retroactivity
- Impact on competences
- Contributive final grade
- Grade estimation
- Dynamic assignments

The key-concepts and sequence of implementation could be resumed as follow:

- The method does not introduce new instruments of evaluation. It is based on the existing ones with special emphasis in active learning and flipped learning.

- The assessment method is based on the concept of execution of activities. An activity is referred to as any learning item or task included in the student curriculum.
- As many activities as possible are included in the assessment process.
- It is a formative assessment process, generating immediate feedback after the activities' execution encouraging the adoption of corrective measures in time to increase the efficiency of the learning process.
- Activities are grouped into topics. The topics need to be arranged in sequences that enable the student an orderly understanding of the concepts. We have called this sequences chain of topic.
- Chain of topics, in general, ends in summative moments of evaluation as a review of all the activities executed with one or more topics.
- A relationship of partial order exists between the chains of topics.
- The assessment process tries to measure the development of the basic mathematical competences (in the sense of Niss).
- There exists a relationship between topic, activity and competence. We establish this relationship by a quantification of the impact on the development of each basic competence through the execution of activities-type in a topic. These quantifications have been arranged in a three dimensional matrix that we have called master ATC cuboid.
- An activity is evaluated from the point of view of the basic competences assigning a binary value which represent if the desired impact of the activity on the competence have been successfully covered. We have called this action binary assessment and it is an application of the concept of assessment by rubrics where a rubric is the description of the competence to be evaluated.
- The students' activities are registered in a data structure called activities backlog that contains an identification of the activity and the binary assessment of its execution.
- Applying the metrics defined in the master ATC to activity backlog of each student, we obtain an aggregated data structure that represents the evolution of the student along the course expressed by the relationship between activities, topics and competences. It is the personal ATC cuboid (pATC).

- Due to the relationship between partial order and chains of topics, the execution of activities in a chain requires the knowledge acquired in predecessors' chains. Based on this principle, a retroactivity component is introduced.
- The retroactivity is implemented by the emission of binary vectors of evaluation from the activity in the moment of evaluation in execution towards previous moments of evaluation, thus generating a contributive effect, which has the potential to redeem past gaps.
- The impact of the execution of activities on the development of competences is incremented as the course progresses depending on the major level of experience of competence that the student is supposed to have.

8.1.3 Questions review

Throughout this dissertation we have come up with a few open issues in relation to the different aspects of continuous assessment procedures and its implications on the measurement of the grade of achievement of basic competences.

Next, we are going to make a survey around these issues.

» Q1: What type of activities should be introduced in the evaluation process?

The instruments with greater added value for assessing competences are those that ensure the collection of varied information and demonstrate the acquisition of personal resources in order to become a qualified person in a future exercise of the professional activity.

For this reason, the evaluation process should include as many diverse activities as possible to cover different aspects of competences' development.

In this sense, key competences such as mental arithmetic, planning for solving problems, written and oral presentations, critical thinking and so forth require a great and varied quantity of activities in order to map these many different aspects and assure that all aspects of the competences' acquisition are covered.

In Mathematics, at ETSID, in addition to lectures, lab practices and written exams, other type of activities have been included in the assessment process. Assignments include sets of problems to solve outside the class combined with a multi-choice to answer in class during a short period of time covering questions about the home assignment. We have also introduced flipped learning techniques in lab practices as an instrument to increase the learning efficiency of the lab class.

Finally, it is important to emphasize that all those activities that have a formative impact on the learning process might be included in the assessment process. Furthermore, the immediate feedback obtained and the continuous contribution system are an incentive for the students and, as a consequence, a continuous strong engage to the method over time will produce a major consolidation of knowledge in due time and, in short, a major efficiency of the learning process.

» Q2: How does the execution of different types of activities contribute to the development of mathematical competences?

In Section 3.4.4 we have exposed how students can develop their competences by solving a problem. As we stated at the end of the problem, improving several competences is embedded within the execution of activities when these are being carefully designed in order to force students to think and reason instead of simply reproducing procedures.

Thus, as we have seen along this work, different activities are carried out in different ways and with different impact on basic competences. In Section 3.5 we have reviewed the most common activity-types that are used in education.

To study how an activity affects which competences and to what extent is a time consuming task. Then, it is important to preserve this work of activity-design. The studied master ATC is the structure in which we express the impact an activity has on the competences and the bank of activities is a data lake where save this knowledge.

Another important concept studied in this dissertation is chains of topics, which help to implement learning paths and, therefore, represent an orderly succession of activities within a sea of topics to get in a structured way the development of competences.

» Q3: Could we establish an assessment process that runs parallel to the learning process?

This question comes by implementing an intensive execution of a great variety of activities covering the whole curriculum from the perspective of the competences. Thus, it is strongly connected with question Q1 and Q2.

When we evaluate an activity and the result is immediately visible to the students generating a current of active feedback, the evaluation turns over a formative activity because, at that time, students are still in the context of the activity execution. The received feedback is going to allow them to analyze, in-context, their fails and successes. Then, they could either be redirected to the way of reinforcement and corrective actions or confirmed about their success.

Therefore, the assessment process runs parallel to the learning process because all the evaluated activities, except summative ones, are converted in true formative activities, step by step and in due time, creating a formative sequence along the formative cycle.

» Q4: Could the assessment process deal with different students learning needs?

Different students might have different learning needs depending on their previous knowledge, capacity of study, some special difficulties or limitations and also other type of circumstances.

In some education systems there is a certain individualization capacity both in the programming of the subjects and in the execution in-class where the teacher dedicates some specific time to some students. However, it is a task that takes lots of time and resources.

A way to attend different learning needs is the method being able of assign different set of activities to students depending on their results and needs. To build a system that could deal with this feature we need two main components: a media containing diverse sets of activities and an algorithm to compute what type of activities are necessary to redirect the student on the way to achieve the desired level of competence.

In this sense, the described method gives enough information about the relationship between activities, topics and level of achievement of competences to generate different sets of activities to attend different learning needs.

» Q5: How could students obtain a right feedback to direct them to achieve the targets?

Giving feedback should be the main objective of a formative assessment procedure as a mean to know how well a set of formative activities is executed.

If the feedback is obtained immediately after the execution of an activity, the student is still in the mental context of the execution; then, for him, to make learning enrichment corrections is much more effective than the delay of this feedback out of the due context.

Additionally, the active/retroactive component introduced in the model aims to identify those competencies that have and those that have not adequately been achieved and, accordingly, add forward and backward corrections over their punctuation reflecting their proven real level of competence at the ulterior given moment of evaluation. Thus, it is a tool that enables to recognize and award improving previous competences in the topic's chain or propose reinforcement activities.

This model of continuous assessment is intended to give an overall assessment of the performance based on competences. When gaps are detected in previously assessed skills, the model tries to bring these results into question independently of the fact that they had not been detected previously. This situation can occur because of several reasons such as a random component about the performance measure since not all contents are always evaluated, a possible degradation in the skills of the student as a result of a weak learning; or just because of defects of the evaluation process itself.

This continuous assessment model tries to give less importance to the achievements based on traditional examinations by introducing a lot of different types of assessed activities that are adding contributions to the main moments of evaluation. The retroactivity is a tool that enables recommended sets of activities of reinforcement to redeem this type of situations looking after the development of all the competences foreseen in the syllabus. Thus, it may become a motivation tool and a guide for students on how to meet their objectives.

» Q6: Which way should we assess the execution of activities bearing in mind the achievement of competences?

As we have studied in Chapter 5, each activity is evaluated from the perspective of the eight competences by means of a binary evaluation of each competence based on an assessment by rubrics with a true/false punctuation depending of the success of the execution.

The objective of an assessment's competence is to measure the progress in the achievement of skills, but in any educational system students may be graded with a final mark on the subject. ATC cuboids are structures in a way that allow us to make both things.

The binary evaluation marks -in the context of the execution of an activity- whether the development of each basic competence (calculation accuracy, use of formal language, ability to understand, etc.) is fulfilled. By means of weights that measure the impact of each activity on each of the basic competencies we can obtain an evaluation of their outcomes as well as a grade for the activity. In a way, weights might be adapted so that the grade calculation provides similar results to a traditional evaluation. This is possible seeing that the measurement of the impact of each of the competencies discretizes the perception of the evaluator who observes the result of an activity execution as a whole.

» Q7: Can the ATC's matrix provide an internal representation of a student's learning progress?

ATC cuboids contain the aggregated measures of the level of achievement of each competence within a topic and an activity type from the execution of all activities done by students. In this sense, the ATC cuboid is an internal representation of the student's learning progress.

The more activities introduced in the ATC cuboid the better the representation of the student's progress will be and a closer the evaluation will take continuous assessment. Different activities have different relevancy as this structure supports the execution of daily activities as well as control points or examinations. Furthermore, GIA|CAP allows redeeming the effects of failed executions in the context of a continuous assessment and also increments the contribution of the activities execution to final grade.

To obtain the personal ATCs, the master ATC cuboids represents the metrics that allow quantifying the binary assessment vector of executed activities to be put into personal cuboids.

» Q8: Could the ATC's matrix be useful to individualize each student's curriculum in order to get his/her individual objectives within a generalized course plan?

Given that ATC cuboids are a representation of the level of competences achievement, we can identify in the ATC structure areas in which the achievement of competences is poorly achieved or not at all.

With this information, either we or an algorithm, can select a set of activities to help the student redeem this situation.

As we have seen in Chapter 5, we can put our educational objectives into precompiled cuboids to establish different target levels. These ATC cuboids are references to be achieved and they are the tools to build up the individualized strategies with the aim of reaching the course objectives.

After that, as we have developed in Chapter 7, dynamic assignments by means of algorithms will be provided to allow the selection of sets of adequate activities for students to reach predetermined objectives.

8.2 Future work

Concluded this dissertation, we may write down some lines of work and investigation that might be tackled for improving the application of a continuous assessment procedure based on feedback and continuous improvement.

In Chapter 7 we have drawn up a schema of data structures needed to support the procedure. Applying this procedure requires the generation of unary activities from each learning instrument used in the course. As we have seen in Chapter 6: lectures, each one of the question of written exams, each lab item developed at lab sessions, assignments, and so on, generate a great quantity of activities. Thus, the students of a course generate a backlog with thousands of activities registered.

A future work, necessary in order to use the ATC assessment procedure consists in developing a set of computer applications which would allow the subject's responsible faculty to manage the model with a reasonable and feasible cost.

Giving immediate feedback after executing activities is a key aspect in formative learning. We think that it would be a helpful tool to develop an ATC Continuous Assessment Dashboard containing key performance indicators (KPI) about the level of achievement of competences along the course, distance from final objectives, group comparatives and so on. The ATC cuboids generate enough information to build a dashboard referring academic performance from several points of view: the student, the person in charge of the subject and the academic institution.

There exist many initiatives on this matter known as *Learning Intelligence*. We can see an introductory review in *The Uses of Management Information and Technology in Higher Education* (Goldstein, 2005).

A relevant line of research would consist in developing better algorithms for dynamic assignments which is a key concept to reach more inclusive systems of evaluation taking into account the diversity of learning needs of the students.

With the use of mathematical predictive techniques, it may be possible to develop models based on student characteristics aimed to recommend activities and formative moments of evaluation in such a way that some given objectives (pass a topic, get a certain score, etc.) may be achieved.

There could be at least four possible approaches to develop the models:

- Potential and Gap

  This approach would consist in doing a segmentation of students according to sociodemographic and educational background. Analysis of patterns in the explanatory variables of students with better grades in each segment would follow. The goal would be to establish the gap between each student situation and the best patterns.

- Paths

  Path Analysis of the ATC roads that give better exam results would allow to identifying different paths that achieve a certain goal. The events to be modeled would be each of the discrete possible grades (from 0 to 10, for example) in each Topic.

- Predicting score

  This approach would consist in doing a regression of qualification variables in a topic in terms of the manageable variables that aggregate evolutionary historic ATC information about a student; for example: number of activities held for each topic, average evaluation of any activity type, etc. This approach would allow recommending values in the manageable explanatory variables for any student depending on his/her situation in the rest of variables.
- Behavioral Segmentation

  Segmentation of students according to their behavior ATC variables would allow searching for different performance patterns (topic score distribution) in different segments, to identify those with better score distributions and to describe their behavioral characteristics as "behaviors for success".

In general the target of these models will be the objective to be achieved by the student and the explanatory variables will be the characteristics of students and their evolutionary ATC cubes, that is, information on progressive acquisition of competences through successive realization of activities on different topics.

These data mining techniques have been widely used in education. We can find some examples in (Darmanegara, Arief, Shun and Nie, 2007), (Browne and Cudeck, 1993), (Baker and Yacef, 2009), (Jing, 1996) and many others. ATC structures provide enough information to fuel this type of predictive models.

References

[1] Alfaro, M. (2000). Evaluación del aprendizaje. Maracaibo: IUPEL.

[2] Alpers, B. and M. Demlova (2012). Competence acquisition in different learning arrangements. Proceedings 16th SEFI MWG Seminar Mathematical Education of Engineers, Salamanca 2012. Available at: http://sefi.htwaalen.de/Seminars/Salamanca2012/16thSEFIMWGSeminar/ficheros/lecturas/Documents_pdf/Session3/SEFIMWG12_Alpers.pdf, (accessed 26 January 2015).

[3] Álvarez Méndez, J. M. (2005). Evaluar para conocer, examinar para excluir. España: Morata. Segunda Edición.

[4] Airasian, P. W. (1991). Classroom assessment. New York. Ed McGraw-Hill.

[5] Airasian, P. W. and Russell, M. K. (2008). Classroom assessment: Concepts and applications (6th ed.). New York: McGraw-Hill.

[6] Alexander W. Astin (1985). Achieving Educational Excellence. San Fran-cisco: Jossey Bass.

[7] Andrade, H. (2000). Using rubrics to promote thinking and learning. Educational Leadership, 57(5), 13–18.

[8] Arter, J. and McTighe, J. (2001). Scoring rubrics in the classroom: Using performance criteria for assessing and improving student performance. Thousand Oaks, CA: Corwin Press/Sage Publications.

[9] Atkin, J. M. and Black, P. (Eds.) (2005). Changing the Subject: Innovations in Science, Maths and Technology Education. Routledge.

[10] Aubrey, R. (1982). Program Planning and Evaluation: Roal Map of the 80's, in Elementary School Guidance, 15; 188-193.

[11] Baartman, L.K.J.; Bastiaens, T.J.; Kirschner, P.A. and Van der Vleuten, C.P.M. (2006). The Wheel of Competency Assessment: Presenting Quality Criteria for Competency Assessment Programs.Studies in Educational Evaluation, 32:153-170.

[12] Baker, Ryan S.J.D. and Yacef, Kalina. (2009). The State of Educational Data Mining in 2009: A Review and Future Visions. School of Information Technologies, University of Sydney

[13] Baxter, G. P.; Elder, A. D. and Glaser, R. (1996). Knowledge-based cognition and performance assessment in the science classroom. Educational Psychologist, 31(2), 133-140.

[14] Beck, L. and Chizhik, A. (2013). Cooperative learning instructional methods for CS1: Design, implementation, and evaluation. ACM Transactions on Computing Education (TOCE) - Special Issue on Alternatives to Lecture in the Computer Science Classroom 13, 3 (Aug. 2013, Article No. 10). DOI = 10.1145/2492686.

[15] Bergmann, J.; Overmyer, J. and Wilie, B. (2013). The Flipped Class: What it is and What it is Not. Retrieved September 1, 2014 from http://www.thedailyriff.com/articles/the-flipped-class-conversation-689.php

[16] Biggs, J. B. (1993). What do inventories of students' learning processes really measure? A theoretical review and clarification. Br. J. Educ. Psychol. 63: 3–19.

[17] Biggs, J. (2002). Aligning the curriculum to promote good learning. A paper written for the Constructive Alignment in Action: Imaginative Curriculum Symposium, 4th November 2002 [online]. Available on the LTSN Generic Centre website http://www.ltsn.ac.uk/.

[18] Biggs, J. B. (2003). Aligning teaching and assessment to curriculum objectives. The Higher Education Academy.

[19] Bilton John (2014). Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. Higher Education Research & Development ahead-of-print (2014): 1-14. Esher High School.

[20] Birenbaum, M.; Breuer K.; E. Cascallar et al. (2006). A Learning Integrated Assessment System. Editors: Wiesemes, R. and Nickmans, G. (available on http://community.dur.ac.uk/smart.centre1 /publications/EARLI%20Position%20paper%201%20assessment.pdf).

[21] Bishop, J. L. and Verleger, M. A. (2013, June). The flipped classroom: A survey of the research. In ASEE National Conference Proceedings, Atlanta, GA.

[22] Black, P. and Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. Phi Delta Kappan, 80 (2): 139-148.

[23] Blanes, A.; Mínguez, F.; Moraño, J.A.; Roselló, M.D. and Sánchez Ruiz, L.M. (2014). Whole Mathematics Competences Assessment at Aerospace Engineering Sophomore. 2014 IEEE Frontiers in Education Conference Proceedings, pp 3036-3039. 22-25 October 2014. Madrid, Spain. IEEE Catalog Number: CFP14FIE-ART. USB version, IEEE Catalog Number: CFP14FIE-USB. ISBN: 978-1-4799-3921-3

[24] Blank, W.E. (1982). The competency-based approach to education and training. Handbook for Developing Competency-Based Training Programs, Prentice-Hall, Englewood Cliffs, NJ, 1982,pp.3-27.

[25] Block James H. (1970). Mastery Learning. New York: Holt, Rinehart and Winston, Inc.

[26] Bloom, B.S.; Hastings, J.T. and Madaus, G.F. (1971). Handbook on Formative and Summative Evaluation of Student Learning. New York: McGraw-Hill.

[27] Bloom Benjamin S. (1976). Human Characteristics and School Learning. New York:McGraw-Hill Book Company.

[28] Bonk, C. J. and Reynolds, T. H. (1997). Learner-centered Web instruction for higher-order thinking, teamwork, and apprenticeship. In B. H. Khan (Ed.), Web-based instruction (pp. 167-178). Englewood Cliffs, NJ: Educational Technology Publications.

[29] Bonwell; Charles C. and Eison, James A. (1991). Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports. ISBN-1-878380-06-7.

[30] Boud, D. (1991) Implementing student assessment. Higher Education Research and Development of Association of Australasia, Sydney.

[31] Boulmetis, John and Dutwin Phyllis (2005). The ABCs of evaluation: timeless techniques for program and project managers. 2st edition. John Wiley & Sons Inc. 2005. ISBN 0-7879-7902-3.

[32] Brookhart S.M. (2013). How to Create and Use Rubrics for Formative Assessment and Grading, ASCD Store, ISBN-13: 978-1-4166-1507-1.

[33] Broughton, Stephen; Robinson, Carol L. and Hernandez-Martinez, Paul. (2012). Lecturers' beliefs and practices on the use of computer-aided assessment to enhance learning. Mathematics Education Centre, Loughborough University, United Kingdom

[34] Brown, S. (2004). «Assessment for Learning». Learning and teaching in Higher education, nº 1, pp. 81-89. Available on www2.glos.ac.uk/offload/tli/lets/lathe/issue1/ articles/brown.pdf (accessed in Marz 2015).

[35] Brown, S; Rust C. and Gibbs, G. (1994). Strategies for Diversifying Assessment, Oxford: Oxford Centre for Staff Development.

[36] Brown, S. and Smith, B. (1997) Getting to Grips with Assessment, Birmingham: SEDA Publications

[37] Browne, M. W., and Cudeck, R. (1993). Alternative ways of assessing model fit. In K. Bolen & J. Long (Eds.). Testing structural equation models (pp. 136–162). Newbury Park, CA: Sage.

[38] Bunk, G.P. (1994). Teaching competence in initial and continuing vocational training in the Federal Republic of Germany. Vocational Training European Journal, Vol.1, pp. 8-14.1994.

[39] Cabrera, Dan. (2013). Tips to Reduce the Impact of Cheating in Online Assessment. Faculty Development and Instructional Design Center Blog, Northern Illinois University, Retrieved September 1, 2014 from http://facdevblog.niu.edu/onlinecheating.

[40] Carliner, S. (1999). Overview of online learning. Amherst, MA: Human Resource Development Press.

[41] Carr, J. (2000). Technical issues of grading methods. In E. Trumbull & B. Farr (Eds.), Grading and reporting student progress in an age of standards, pp. 45 - 70. Norwood, MA: Christopher Gordon.

[42] Carr, M.; Murphy, E.; Bowe, B. and Ni Fhloinn, E. (2013). Addressing Continuing Mathematical Deficiencies with Advanced Mathematical Diagnostic Testing. Teaching Mathematics Applications 32 (2), 66-75. First published online April 10, 2013 doi:10.1093/teamat/ (accessed 26 January 2015).

[43] Carroll, John B. (1963). A Model of School Learning. Teachers College Record, 64(1963): 723-733

[44] Chadwick, C. and Rivera, N. (1991). Evaluación formativa para el docente. Barcelona: Paidós.

[45] Chickering, Arthur W. and Gamson, Zelda F. (1987, March). Seven Principles for Good Practice. AAHE Bulletin 39:3-7. ED 282 491.6 pp. MF-01; PC-01.

[46] Chism, Nancy; Jones, Christopher; Macce, Barbara and Mountford, Roxanne. (1989). Teaching at The Ohio State University: A Hand-book. Columbus: Ohio State Univ., Center for Teaching Excellence.

[47] Chomsky, N. (1980). Rules and representations. The Behavioral and Brain Sciences, 3, 1-61.

[48] Clark, R. E. (1983). Reconsidering research on learning from media. Review of Educational Research, 53(4), 445-459.

[49] Clement, J. (2000). Model based learning as a key research area for science education. International Journal of Science Education 22 (9): 1041–1053. doi:10.1080/095006900416901.

[50] Cole, R. A. (2000). Issues in Web-based pedagogy: A critical primer. Westport, CT: Greenwood Press.

[51] Coll, César; Rochera, María J.; Mayordomo, Rosa M. and Naranjo, Mila. (2007). Continuous assessment and support for learning: an experience in educational innovation with ICT support in higher education. Education Journal of Research in Educational Psychology, N. 13 Vol 5, 2007 ISSN 1696-2095, pp. 783-804.

[52] Conselleria d'Educació, Cultura i Esports. DG Innovació, Ordenació i Política Lingüística. Servici d'Avaluació i Estudis 2013. Evaluación de diagnóstico en la Comunidad Valenciana.

[53] Cross, K. Patricia. (1987). Teaching for Learning. AAHE Bulletin 39:3-7. ED 283 446. 6 pp. MF-01; PC-01.

[54] Darmanegara Liem, Arief ; Shun Lau and Nie Youyan. (2007). The role of self-efficacy, task value, and achievement goals in predicting learning strategies, task disengagement, peer relationship, and achievement outcome. Centre for Research in Pedagogy and Practice, National Institute of Education, Nanyang Technological University, Singapore.

[55] Davies, R. S., Dean, D. L. and Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. Educational Technology Research and Development, 61(4), 563-580.

[56] Demetry, C. (2010). An innovation merging Classroom Flip and Team-Based Learning. 40th ASEE/IEEE Frontiers in Education Conference. (October 2010). Session T1E.

[57] Díaz-Barriga, S. (2006). Estrategias docentes para un aprendizaje significativo. México, Mc Graw Hill.

[58] Downes, S. (2000). Learning Objects: Resources for Distances Education Worldwide. International Review of Research in Open and Distance Learning 2 (1) 2000.

[59] Edwards M.; Sánchez Ruiz, L.M. and Sánchez-Díaz, C. (2009). Achieving competence based curriculum in engineering in Spain. Proceedings of the IEEE Vol. 97 (10), pp 1727-1736.

[60] Eplion, D.M. and Keefe, T. J. (2007). Practical Tips for Preventing Cheating on Online Exams. Distance Education Report, Vol. 11 (no 8), p. 4.

[61] Ericksen and Stanford Clark. (1984). The Essence of Good Teaching. San Francisco: Jossey-Bass.

[62] European Commission, Directorate-General for Education and Cultures (2009) "ECTS users' guide". Accessed via: http://ec.europa.eu/dgs/education_culture/ (7 September 2015).

[63] Ezewu, E.E. and Okoye, N.N. (1986). Principles and practice of continuous assessment. Ibadan: Evans Publishers.

[64] Ewell, P.T. (1984). The Self-Regarding Institution: Information for Excellence. Boulder, Colo.: National Center for Higher Education Management Systems.

[65] Falayajo Wole (1986). Philosophy and theory of continuous assessment. In: Workshop for Inspectors of Education, Odor State, Nigeria. 4th December.

[66] Fischer, S. (2001). Course and Exercise Sequencing Using Metadata in Adaptive Hypermedia Learning Systems. ACM Journal of Educational Resources in Computing, 1(1), Spring 2001.

[67] Foyster, John. (1990). Competency-based training programs, Getting to Grips with Competency-Based Training and Assessment, TAFE National Centre for Research and Development, Leabrook, SA, 1990, pp.20-32.

[68] García, A.; García, F.; Martín, A.; Rodríguez, G. and Villa, A. de la (2012). Learning and Assessing Competencies: New challenges for Mathematics in Engineering Degrees in Spain. 16th SEFI MWG Seminar Mathematical Education of Engineers. Salamanca (Spain).

[69] Garrison, D. R. and Shale, D. (1990). A new framework and perspective. In D. R. Garrison & D. Shale (Eds.), Education at a distance: From issues to practice (pp. 123-133). Malabar, FL: Robert E. Krieger.

[70] Gibbs, G. (1992). Improving the Quality of Student Learning. Technical & Educational Services Ltd.

[71] Gibbs, G. and Simpson, C. (2004). Conditions under which assessment supports students' learning. Learning and Teaching in Higher Education, 1, 3–31.

[72] Glick, D.; Henning, M. J. and Johnson, J. R. (1974). How to prevent a second orthodoxy. Education Technology. 1974, August, 17-20.

[73] Goldstein, Philip J. (2005). Academic Analytics: The Uses of Management Information and Technology in Higher Education. EDUCASE Center for Applied Research. Accessible on https://www.educause.edu/ecar

[74] Gómez Arbeo, B. M. (1990). Evaluación criterial (una metodología útil para diagnosticar el nivel de aprendizaje de los alumnos). Madrid, Narcea.

[75] González, J. and Wagenaar, R. (Eds.) (2003). Tuning Educational Structures in Europe. University of Deusto and Groningen: Deusto. 2003

[76] Gonzci, A. and Athanasou, J. (1996). Instrumentación de la Educación basada en Competencias. Perspectivas de la teoría y práctica en Australia. In: Competencia Laboral y Educación Basada en Normas de Competencia. SEP. CNCCL. CONALEP. México. 1996

[77] Grant, G. et al. (1979). On Competence: A Critical Analysis of Competence-Based Reforms in Higher Education. Jossey-Bass Publishers, San Francisco: CA. 1979

[78] Grijalva, T. C.; Nowell, C. and Kerkvliet, J. (2006, March). Academic honesty and online courses. College Student Journal, 40(1), 180-185.

[79] Guba, E. and Lincoln. (1989). Fourth Generation Evaluation. Newbury Park: Sage publications. California. USA.

[80] Hafner, J. and 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.

[81] Harlen, Wynne and James, Mary. (1997). Assessment and Learning: differences and relationships between formative and summative assessment. Assessment in Education: Principles, Policy & Practice, 4: 3, 365 — 379.

[82] Hoffmann, M.H.W. (2011a). When to assess knowledge, skills, and competences. In: Welzer-Družovec, Hoffmann (eds.), “2011 – EAEEIE Annual Conference”, Maribor, Slovenia, 2001, pp. 140-144.

[83] Hoffmann, M.H.W. (2011b). Fairly Certifying Competences, Objectively Assessing Creativity. In Proc. IEEE Global Engineering Education Conference (EDUCON 2011), pp. 270 – 277. Amman (Jordan) of EDUCON 2011.

[84] Honeycutt, B. and Garrett, J. (2014). Expanding the definition of a flipped learning environment. Instructional Design: Faculty focus.

[85] Hughes, H. (2012). Introduction to Flipping the College Classroom. In T. Amiel & B. Wilson (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2012 (pp. 2434-2438). Chesapeake, VA: AACE. Retrieved September 13, 2014 from http://www.editlib.org/p/41097.

[86] Idowu, A.I. and Esere, M.O. (2009). Assessment in Nigerian schools: a counsellor’s viewpoint. Edo Journal of Counselling Vol. 2, No. 1, 17-27.

[87] Jackson N. (2000). Programme specification and its role in promoting an outcomes model of learning, Active Learning in Higher Education, 1.2, pp 132-151.

[88] Jing, H. J. (1996). The impact of learner's pathways on learning performance in multimedia Computer Aided Learning. Journal of Network and Computer Applications 19 (4).

[89] Khan, B. (1997). Web-based instruction: What is it and why is it? In B. H. Khan (Ed.), Web-based instruction (pp. 5-18). Englewood Cliffs, NJ: Educational Technology Publications.

[90] King, S.O.; Davis, L; Robinson, C.L. and Ward, J.P. (2008). Use of Voting Systems in Lectures at Loughborough University - A Review of Staff Experiences. Mathematics Education Centre, Loughborough University, LE11 3TU, UK.

[91] Kleiner, C. and Lord, M. (1999). The cheating game: Cross-national exploration of business students' attitudes, perceptions, and tendencies toward academic dishonesty. Journal of Education for Business. 74(4), 38-42.

[92] Kozma, R. B. (2001). Counterpoint theory of "learning with media." In R. E. Clark (Ed.), Learning from media: Arguments, analysis, and evidence (pp. 137-178). Greenwich, CT: Information Age Publishing Inc.

[93] Laboratory Network Program (1993). A Tool Kit for Professional Developers: Alternative Assessment. Portland, Oregon: Northwest Regional Educational Laboratory.

[94] Lage, G.J.; Platt and Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. The Journal of Economic Education, 31(1):30–43, 2000.

[95] Lancaster, J.; Waught, L. and Wood, J. (2008). Designing and Implementing Student-Centered Assessment. Annual Assessment Conference. Texas AandM University. http://assessmentconference.tamu.edu/resources/conf_2008_presentations/Wood_StudentCenteredAssessment.pdf (accessed September 7, 2015).

[96] Lasnier, F. (2000). Réussir la formation par compétences. Guérin: Montreal.

[97] Levy-Leboyer, C. (1997). Gestión de las competencias: cómo analizarlas, cómo evaluarlas, cómo desarrollarlas. Barcelona: Gestión 2000.

[98] Legua, M.; Moraño, J.A. and Sánchez Ruiz, L.M. (2010). Fundamentos de Álgebra Lineal y Aplicaciones. Editorial de la UPV, Valencia.

[99] Leplat, J. (1997). Regards sur l'activité en situation de travail. Contribution à la psychologie ergonomique. Paris: PUF.

[100] Linn, R. L. and Gronlund, N. E. (1995). Measurement and assessment in teaching, Seventh edition. New York: Macmillan.

[101] Llobregat-Gómez, N.; Mínguez, F.; Moll, S.; Moraño, J.A.; Roselló, M.D. and Sánchez Ruiz, L.M. (2014). An essential catalyzer in mathematics engineering education: Using an education platform in Aerospace Engineering. Submitted.

[102] Luan Jing (2002). Data mining is the process of discovering "hidden messages," patterns and knowledge within large amounts of data and of making predictions for outcomes or behaviors. New Directions For Institutional Research, no. 113, Spring 2002 © Wiley Periodicals, Inc.

[103] Mantz Yorke (2003). Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice. Higher Education 45: 477–501, 2003. Kluwer Academic Publishers.

[104] Marina, J.A. (2011). Memoria y Aprendizaje. Pediatría Integral, 15 (10), 978-980.

[105] Mathematics Working Group SEFI (2013). A Framework for Mathematics Curricula in Engineering Education, Third edition (Alpers et all Eds.). Available at http://sefi.htw-aalen.de/Curriculum (accessed 1 May 2014).

[106] McClelland, C. (1973). Testing for Competence Rather Than 'Intelligence. American Psychologist, Vol. 28, no. 1, pp. 1-40. 1973.

[107] McMurtry, K. (2001). E-cheating: Combating a 21st century challenge. THE Journal Online: Technological Horizons in Education. Retrieved June 11, 2002,

[108] Mawhinney, V.T.; Bostow, D.E.; Laws, D.R.; Blumenfeldm G.J. and Hopkins, B.L. (1971). A comparison of student's studying-behavior produced by daily, weekly, and three-week testing schedules, J. Appl. Behav. Anal. 4 (1971), pp. 257–264.

[109] Mertens, Donna M. (2005). Research and evaluation in Education and Psychology: Integrating diversity with quantitative, qualitative, and mixed methods. Thousand Oaks: Sage.

[110] Mertens, Leonard. (1997). Competencia laboral: sistemas, surgimiento y modelos. Cinterfor. Montevideo.

[111] Miller, A.H.; Imrie, B.W. and Cox, K. (1998). Student Assessment in Higher Education: a handbook for assessing performance, London: Kogan Page.

[112] Mínguez, F.; Ferrer, J.R.; Legua, M. and Sánchez Ruiz, L.M. (2013). Evaluating competences in Mathematics at Aeronautical Engineering. Proceedings 41st SEFI Conference, Paper 169, 8 pages. Leuven 16-20 September 2013. http://www.sefi.be/conference-2013/images/169.pdf

[113] Mínguez, F. and Sánchez Ruiz, L.M. (2014). Active/retroactive feedback in continuous assessment of mathematical competences. Proceedings The 17th SEFI Mathematics working Group Seminar (Editors: Burkhard Alpers (HTW Aalen Germany), Michael Carr (Dublin Institute of Technology Ireland), Marie Demlova (Czech Technical University Czech Republic), Tommy Gustafsson (Chalmers University of Technology Sweden), Duncan Lawson (Newman University UK), Brita Olsson-Lehtonen (Finland), Carol Robinson (Loughborough University UK), Paul Robinson (IT Tallaght Ireland), Daniela Velichova (Slovak University of Technology in Bratislava, Slovakia)), 5 pages, Dublin 23-25 June 2014. ISBN: 978-2-87352-011-3.

[114] Mínguez, F.; Moll, S.; Moraño, José-A. ; Roselló, M.D. and Sánchez Ruiz, L.M.(2014). Mathematics Competences Assessment at Lab sessions of Aerospace Engineering Freshmen. TEEM'14 (Technological Ecosystems for Enhancing Multiculturality). ACM Digital Library as a volume in its International Conference Proceedings Series (Editor

F.J. Garcia-Peñalvo), pp. 441-445. Salamanca 1-3 octubre 2014. ISBN: 978-1-4503-2896-8

[115] Mínguez, F.; Moraño, José-A.; Roselló, M.D. and Sánchez Ruiz, L.M.(2014). Towards a continuous assessment of mathematical competencies in a First Year of Aerospace Engineering. Paper 147 at SEFI 42nd Annual Conference. Birmingham, UK, 15th-19th September 2014. Book of Abstracts ISBN: 978-2-87352-010-6.

[116] Mínguez, F.; Llobregat-Gómez, N.; Roselló, M.D. and Sánchez Ruiz, L.M. (2015). Encouraging active learning and creativity within STEM topics. Active Teachers Active Students. 13th Active Learning in Engineering Education Workshop (ALE). International Joint Conference on the Learner in Engineering Education. IJCLE2015, (Eds.: Erik de Graaff, Montse farreras, Nestor A. Arexolaleiba), 322-329. San Sebastián, Mongragon University, 6-10 July 2015. Published by Aalborg University Press. ISBN: 978-87-7112-303-6.

[117] Mínguez, F.; Llobregat-Gómez, N.; Roselló, M.-D. and Sánchez Ruiz, L.M. (2015). Blended Learning Activities Development. Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL), 79-81. Florencia, 20-24 sept 2015. Published by IEEE. ISBN: 978-1-4799-8706-1.

[118] Montgomery, K. (2000). Classroom Rubrics: Systematizing What Teachers Do Naturally, The Clearing House; Education Module, vol. 73, n° 6, pp. 324-329.

[119] Morales, J. J. (2001). La evaluación en el área de Educación visual y plástica en la Educación Secundaria Obligatoria. Tesis doctoral. Bellaterra: Barcelona. http://www.tesisenred.net/bitstream/handle/10803/5036/jjma01de16.pdf.pdf?sequence=1 (accedido en Marzo 2015)

[120] Moraño, J.A. and Sánchez Ruiz, L.M. (2012), Cálculo y Álgebra con Mathematica 8. Editorial de la UPV, Valencia.

[121] Moskal, B. M. (2000). Scoring Rubrics: What, When and How? Practical Assessment, Research and Evaluation, vol. 7, n° 3.

[122] Muriel Green (2002). Initial assessment: a learner centred process. Learning and Skills Development Agency, London. Registered with the Charity Commissioners, ISBN 1 85338 841 6

[123] Niss, M. (2003). Mathematical competencies and the learning of Mathematics: The Danish KOM project. In A. Gagatsis, S. Papastravidis (Eds.), 3rd Mediterranean Conference on Mathematics Education (pp. 115-124), Athens, Greece: Hellenic Mathematical Society and Cyprus Mathematical Society.

[124] Niss, M. and Højgaard, T. (2011). Competencies and mathematical learning. Ideas and inspiration for the development of mathematics teaching and learning in Denmark. English edition, October 2011. Roskilde University. IMFUFA tekst nr. 485/ 2011

[125] OECD (2005). Formative Assessment: Improving Learning in Secondary Classrooms. ISBN-13: 9789264007390. Publication date 11 Feb 2005.

[126] OECD (2009). PISA 2009 Assessment Framework – Key competencies in reading, mathematics and science (accessed http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2009-assessment-framework_9789264062658-en#page3 on 22 April 2015).

[127] OECD (2013), PISA 2012 Assessment and Analytical Framework: Mathematics, Reading, Science, Problem Solving and Financial Literacy, OECD Publishing. http://dx.doi.org/10.1787/9789264190511-en.

[128] Oguneye, W. (2002). Continuous assessment: Practice and prospects. Lagos: Providence Publishers.

[129] O'Farrell, C. (2002). Enhancing student learning through assessment. Dublin: Institute of Technology.http://www.tcd.ie/teaching-learning/academic-development/assets/pdf/2503 09_assessment_toolkit.pdf (accessed on March 2015).

[130] Otter, S. (1992). Learning Outcomes in Higher Education, London: Employment Department, Unit for the Development of Adult Continuing Education.

[131] Overton, U.F. (1985). Scientific methodologies and the competence - moderator - performance issue. In E. Neimark, R. Delisi & J. Newman (Eds.), Moderators of competence (pp. 15-41). Hillsdale, NJ: Erlbaum.

[132] Pello Salaburu; Guy Haug and José-Ginés Mora (2011). España y el proceso de Bolonia, un encuentro imprescindible. Academia Europea de Ciencias y Artes. Isbn: 978-84-614-7183-6. Avalilable on http://www.expertosbolonia.es/wp-content/uploads/2014/03/ Espana-y-el-proceso-de-Bolonia.pdf (accessed on 13 April 2015).

[133] Piaget, J.; Elkind, D. and Tenzer, A. (1967). Six psychological studies. Random House New York.

[134] Pintrich, Paul R. (2004). A Conceptual Framework for Assessing Motivation and Self-Regulated Learning in College Students. Educational Psychology Review, Vol. 16, No. 4, December 2004.

[135] Popham, W. J. (1983). Evaluación basada en criterios. Madrid, Magisterio Español.

[136] Popham, W.J. (1999). Classroom assessment: What teachers need to know (2nd Ed.). Needham Heights, MA: Allyn & Bacon.

[137] Qinghai, Gao. (2012). Using IP Addresses as Assisting Tools to Identify Collusions. International Journal of Business, Humanities and Technology, Vol. 2 (1), 70-75.

[138] Race, Phil. (2001). A Briefing on Self, Peer and Group Assessment. http://phil-race.co.uk/wp-content/uploads/Self,_peer_and_group_assessment.pdf (accessed on March, 2015).

[139] Ramaprasad, A. (1983). On the definition of feedback. Syst. Res., 28: 4–13. doi: 10.1002/bs.3830280103.

[140] Reid, N. (2009). The Concept of Working Memory: Introduction to the Special Issue. Research in Science & Technological Education, 27 (2), 131-137.

[141] Riley, S. M. (1995). Peer responses in an ESL writing class: Student interaction and subsequent draft revision. Dissertation Abstracts International, 56, 3031.

[142] Ring, G. and Mathieux, G. (2002, February). The key components of quality learning. Paper presented at the ASTD Techknowledge 2002 Conference, Las Vegas.

[143] Rockwood, H. S. III. (1995a). Cooperative and collaborative learning. The national teaching & learning forum, 4(6), 8-9.

[144] Rockwood, H. S. III. (1995b). Cooperative and collaborative learning. The national teaching & learning forum, 5(1), 8-10.

[145] Rust, C.; Price, M. y O' Donovan, B. (2003). Improving students' learning by developing their understanding of assessment criteria and processes, Assessment and Evaluation in Higher Education, 28, 2: 147-164.

[146] Ryan, Michael P. and Gretchen G. Martens. (1989). Planning a CollegeCourse; A Guidebook for the Graduate Teaching Assistant. AnnArbor, Mich.: National Center for Research to Improve Postsec-ondary Teaching and Learning.

[147] Rychen, S. and Tiana, A. (2004). Developing Key Competencies in Education: Some Lessons from International and National Experience, Geneve: UNESCO-IBE, Studies in Comparative Education.

[148] Sánchez-Ruiz L.M.; Edwards, M. and Ballester-Sarrias, E. (2006). Competence learning challenges in Engineering Education in Spain: from theory to practice. 9th International Conference on Engineering Education, San Juan PR.

[149] Sánchez Ruiz, L.M and Legua Fernández, M. (2008), Cálculo Matemático con Aplicaciones. Editorial de la UPV, Valencia.

[150] Sánchez-Ruiz, L.M. and Moraño, J.A. (2010). Mathematics for Engineering from a platform based in the project Sakai. In Conference Proceedings International Conference on Engineering Education ICEE. Silesian University of Technology, Gliwice (Poland) 18-22 July, Paper 1084_1241.

[151] Schafer, W.; Swanson, G.; Bené, N. and Newberry, G. (2001). Effects of teacher knowledge of rubrics on student achievement in four content areas. Applied Measurement in Education, 14(2), 151-170.

[152] Schramm, W. (1977). Big media, little media. Beverly Hills, CA: Sage.

[153] Scriven, M. (1967). The methodology of evaluation. In R. E. Stake (Ed.), Perspectives of curriculum evaluation (Vol. 1, pp. 39-55). Chicago: Rand McNally.

[154] Sembill, D. (1992). Problemlösefähigkeit, Handlungskompetenz und emotionale Befindlichkeit. Göttingen: Hogrefe.

[155] Shepard, L. A. (2008). Formative assessment: caveat emptor. In C. A. Dwyer (Ed.), The future of assessment: shaping teaching and learning (pp. 279-303). Mahwah, NJ: Lawrence Erlbaum Associates.

[156] Shortera, N.A. and Young, C.Y. (2012). Comparing assessment methods as predictors of student learning in an undergraduate mathematics course. International Journal of Mathematical Education in Science and Technology, Vol. 42, No. 8, 1061–1067.

[157] Sims, R. (1999). Interactivity on stage: Strategies for learner designer communication. Australian Journal of Educational Technology, 15(3), 257-272. Retrieved June 26, 2015, from http://www.ascilite.org.au/ajet/ajet15/sims.html

[158] Slomson, A. (2010). What makes a good maths lecture? MSOR Connections, 10, 17-20.

[159] Staker, H. and Horn, M. B. (2012). Classifying K-12 Blended Learning. Innosight Institute.

[160] Sternberg, R.J. (1996). Successful intelligence. New York: Simon & Schuster.

[161] Stiggins, R. J. (2001). Student-involved classroom assessment (3rd edition). Upper Saddle River, NJ: Merrill/Prentice-Hall.

[162] Stufflebeam, D.L. and Shinkfield, A.J. (1989). Evaluación sistemática. Guía teórica y práctica. Barcelona, Paidós/MEC.

[163] Talbert, R. (2014). The Inverted Calculus Course: Using Guided Practice to Build Self-Regulation. Web log post. “Casting Out Nines.” Chronicle of Higher Education, 4 March 2014. Web. 20 July 2015. http://bit.ly/1kWlBoT.

[164] Tardif, J. (2006). L’évaluation des compétences. Documenter le parcours de développement. Montréal: Chenelière Éducation.

[165] Terenzini, Patrick T. (1989). Assessment with open eyes: Pitfalls in studying student outcomes. Journal of Higher Education, Vol. 60, No. 6, pp. 644-664.

[166] Toto, R. and Nguyen, H. (2009). Flipping the work design in an industrial engineering course. 39th ASEE/IEEE Frontiers in Education Conference. (October 2009), Session T4F.

[167] Tyler R.W. (1967). Changing concepts of educational evaluation, in STAKE, R.E. (Com.): Perspectives of Curriculum Evaluation, vol 1. New York, Rand McNally.

[168] Universidad Alfonso X El Sabio, Grado de Ingeniería Aeroespacial, Plan de Estudios, http://www.uax.es/grado-en-ingenieria-aeroespacial.html (Documents accessed on September 7, 2015)

[169] Universidad de Cádiz, UCA, Grado de Ingeniería Aeroespacial, Ficha de asignaturas 2015-2016 (Documents accessed on September 7, 2015) http://asignaturas.uca.es/wuca_asignaturasttg1516_asignatura?titul=21716&asign=21716006&dpto=C101
http://asignaturas.uca.es/wuca_asignaturasttg1516_asignatura?titul=21716&asign=21716011&dpto=C101
http://asignaturas.uca.es/wuca_asignaturasttg1516_asignatura?titul=21716&asign=21716001&dpto=C101
http://asignaturas.uca.es/wuca_asignaturasttg1516_asignatura?titul=21716&asign=21716022&dpto=C101

[170] Universidad Carlos III de Madrid, Grado en Ingeniería Aeroespacial, Programa de Estudios. (Documents accessed on September 7, 2015): https://aplicaciones.uc3m.es/cpa/cpa/generarReport.do?ano=2015&plan=237&asig

natura=15331&idioma=2
http://www3.uc3m.es/reina/Fichas/Idioma_2/251.15320.html
http://www3.uc3m.es/reina/Fichas/Idioma_2/251.15324.html
http://www3.uc3m.es/reina/Fichas/Idioma_2/251.15321.html

[171] Universidad Europea de Madrid, Laureate International Universities, Grado en Ingeniería Aeroespacial en Aeronaves, Plan de Estudio (Documents accessed on September, 6, 2015): http://campusvirtual.uem.es/moodle/uxxi-mo/verprograma_esp.php?asignatura=9966001106&_ga=1.47870754.425958212.1441711446
http://campusvirtual.uem.es/moodle/uxxi-mo/verprograma_esp.php?asignatura=9966001101&_ga=1.244996224.425958212.1441711446
http://campusvirtual.uem.es/moodle/uxxi-mo/verprograma_esp.php?asignatura=9966001201&_ga=1.47821858.425958212.1441711446

[172] Universidad de León, Grado de Ingeniería Aeroespacial, Plan de estudios, Plan 2010, curso 2015/16, Guía docente (Documents accessed on September 6, 2015) https://guiadocente.unileon.es/docencia/guia_docent/doc/asignatura.php?assignatura=0710001&any_academic=2015_16&idioma=cast&doc=N
https://guiadocente.unileon.es/docencia/guia_docent/doc/asignatura.php?assignatura=0710002&any_academic=2015_16&idioma=cast&doc=N
https://guiadocente.unileon.es/docencia/guia_docent/doc/asignatura.php?assignatura=0710013&any_academic=2015_16&idioma=cast&doc=N
https://guiadocente.unileon.es/docencia/guia_docent/doc/asignatura.php?assignatura=0710006&any_academic=2015_16&idioma=cast&doc=N

[173] Universitat Politècnica de Catalunya, BarcelonaTech, Graus 2015-2016, Enginyeria de Sistemes Aeroespacials i Enginyeria de Sistemes de Telecomunicació o Enginyeria Telemàtica, Guia docent (documents accessed on September 7, 2015): http://www.upc.edu/estudispdf/guia_docent.php?codi=300200&lang=cat
http://www.upc.edu/estudispdf/guia_docent.php?codi=300010&lang=cat
http://www.upc.edu/estudispdf/guia_docent.php?codi=300205&lang=cat

[174] Universidad Politécnica de Madrid, Estudios y Titulaciones, Grado en Ingeniería Aeroespacial, ETSIAE, Asignaturas Primer Ciclo (documents accessed September 8, 2015)
http://www.etsiae.upm.es/ordenacion_academica/ord_gia/plan_estudios/Asignaturas_15_16/matematicasI.pdf
http://www.etsiae.upm.es/ordenacion_academica/ord_gia/plan_estudios/Asignaturas_15_16/metodos_matematicos.pdf
http://www.etsiae.upm.es/ordenacion_academica/ord_gia/plan_estudios/Asignaturas_14_15/matematicasII.pdf
http://www.etsiae.upm.es/ordenacion_academica/ord_gia/plan_estudios/Asignaturas_14_15/estadistica.pdf

[175] Universidad Politécnica de Valencia (2014a). Bachelor's degree in Aerospace Engineering, description programme for Mathematics I, II and III. https://www.upv.es/titulaciones/GIA/menu_920634c.html (accessed on September 7, 2015)

[176] Universidad Politécnica de Valencia. (2014b). Educational Platform PoliformaT. Accessed via http://www.upv.es/perfiles/ pas-pdi/index-en.html.

[177] Universidad Rey Juan Carlos, Estudios de Grado, Ingeniería Espacial en Aeronavegación, Guías Docentes, Curso Académico 2015-16, http://miportal.urjc.es/guiasdocentes/mostrarGuias.jsp (accessed on September, 7, 2015).

[178] Universidad de Sevilla, Estudios y Acceso, Grados, Grado en Ingeniería Aeroespacial, Plan de Estudios (documents accessed on September,5,2015):
http://www.us.es/estudios/grados/plan_197/asignatura_1970012
http://www.us.es/estudios/grados/plan_197/asignatura_1970005
http://www.us.es/estudios/grados/plan_197/asignatura_1970006
http://www.us.es/estudios/grados/plan_197/asignatura_1970009
http://www.us.es/estudios/grados/plan_197/asignatura_1970020
http://www.us.es/estudios/grados/plan_197/asignatura_1970018

[179] Van Merriënboer, J. J. G.; Van der Klink, M. R. and Hendriks, M. (2002). Competencies: van complicaties tot compromis. Over schuifjes en begrenzers. Onderwijsraad report 20020382/598. Den Haag, the Netherlands: Onderwijsraad.

[180] Velichovà, Daniela (2012, June 28th). Multiple Choice Tests Revisited. Mathematical Education of Engineers. 16th SEFI MWG Seminar. Session 5.

[181] Vermetten, Y.; Lodewijks, H. and Vermunt, J. (1999). Consistency and variability of learning strategies in different university courses. Higher Educ. 37: 1–21.

[182] Vermunt, J. (1996). Metacognitive, cognitive, and affective aspects of learning styles and strategies: A phenomenographic analysis. Higher Educ. 31: 25–50.

[183] Villa Sánchez, A. (2008). La excelencia docente. Revista de Educación, número extraordinario 2008, pp. 177-212.

[184] Villa Sánchez, A.; Poblete, M. et al. (2007). Aprendizaje Basado en Competencias. Bilbao: Mensajero. 2ª edición.

[185] Voorhees, R. A. (2001). Competency-Based Learning Models: A Necessary Future. New Directions for Institutional Research, 2001: 5–13. doi: 10.1002/ir.7

[186] Vossen, G. and Jaeschke, P. (2002). Towards a Uniform and Flexible Data Model for Learning Objects. In Proceedings 30th Annual Conf. of the Int. Bus. School Computing Assoc. (IBSCA), Savannah, Georgia, 2002, pp. 99–129.

[187] Vossen, G.; Jaeschke, P. and Oberweis, A. (2002). Flexible Workflow Management as a Central E-Learning Support Paradigm. Proceedings 1st European Conference on E-Learning (ECEL), Uxbridge, UK, 2002, pp. 253–267.

[188] Vossen, G. and Westerkamp P. (2003). E-Learning as a Web Service (Extended Abstract). Proceedings 7th Int. Conf. on Database Engineering and Applications (IDEAS), Hong Kong, China, 2003, IEEE Computer Society Press.

[189] Vygotsky, L.S. (1978). Mind and society: The development of higher mental processes. Cambridge, MA: Harvard University Press, 1978.

[190] Weinert, F.E. (2001). Concept of Competence: a conceptual definition. In: D. S. Rychen & L. H. Salganik (Eds.). Defining and Selecting Key Competencies, p46. Seattle, WA: Hogrefe & Huber.

[191] Wheeler, D.K. (1985). El desarrollo del curriculum escolar. Editorial: Santillana. Madrid, 1985 ISBN 10: 8429413723

[192] White, R.H. (1959). Motivation reconsidered: The concept of competence. Psychological Review, 66, 297-333.

[193] Wiggins, G. (1988). Rational numbers: toward grading and scoring that help rather than harm learning. American Educator, Winter 1988.

[194] William M. Kapambwe. (2009). Continuous Assessment as Relevant Tool to Quality Products or Learners in Education, National Curriculum Symposium, http://es.slideshare.net/wmkapambwe/continuous-assessment-as-a-relevant-tool-to-quality-products-of-learners-in-education.

[195] Wilson, Steve (2001). Using peer- and self-assessment to engage with assessment criteria and learning outcomes: a case study from a course for lecturers. Investigations in University Teaching and Learning vol. 1(2), pp 49-56. London metropolitan university. Centre for Academic professional Development ISSN 1740-5106

[196] Zabalza, A. (1977). El proceso de evaluación, en Didáctica II, Madrid, UNED.

Annex I: ATC data from a sample of students

Next there are written down the ATC assessment results of the students from the selected sample. For each of them we reproduce the activities backlog, the ATC cuboids earlier and after applying the retroactivity effect and the graphs of competences improvement, retroactivity effect and total competences achievement.

I.1 Student A1

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	A1	C1	Test 1	100	P11	1	1	1	0	60	30	10	0	100
2	1	A1	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	A1	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	A1	C1	Test 4	100	P11	0	0	0	0	0	0	0	0	0
5	1	A1	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	A1	C1	Test 6	100	P11	1	1	1	0	60	30	10	0	100
7	1	A1	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	A1	C1	Test 8	100	P11	1	1	1	0	60	30	10	0	100
9	1	A1	C1	Test 9	100	P11	1	1	1	0	60	30	10	0	100
10	1	A1	C1	Test 10	100	P11	1	1	1	0	60	30	10	0	100
11	1	A1	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	A1	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	A1	C1	Exam 1	30	E11	1	1	1	0	40	30	30	0	100
14	1	A1	C1	Exam 2	30	E12	1	1	1	0	40	30	30	0	100
15	1	A1	C1	Exam 3	30	E11	1	1	1	0	40	30	30	0	100
16	1	A1	C1	Exam 4	40	E13	1	1	1	0	40	30	30	0	100
17	1	A1	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	A1	C1	Exam 6	30	E11	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	A1	C2	Exam 1	60	E21	1	1	1	0	40	30	30	0	100
20	2	A1	C2	Exam 2	60	E21	1	1	1	0	40	30	30	0	100
21	2	A1	C2	Exam 3	60	E21	1	1	1	0	40	30	30	0	100
22	2	A1	C2	Exam 4	40	E22	1	1	1	0	40	30	30	0	100
23	2	A1	C2	Exam 5	60	E21	1	1	1	0	40	30	30	0	100
24	2	A1	C2	Exam 6	60	E21	1	1	1	0	40	30	30	0	100
25	2	A1	C2	Exam 7	60	E21	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	A1	A	Exam 1	60	E31	1	1	1	0	40	30	30	0	100
27	3	A1	A	Exam 2	40	E32	1	0	1	0	40	0	30	0	70
28	3	A1	A	Exam 3	60	E31	1	1	1	0	40	30	30	0	100
29	3	A1	A	Exam 4	60	E31	1	1	1	0	40	30	30	0	100
30	3	A1	A	Exam 5	60	E31	1	0	1	0	40	0	30	0	70
31	3	A1	A	Exam 6	60	E31	1	0	1	0	40	0	30	0	70
32	3	A1	A	Exam 7	60	E31	1	0	1	0	40	0	30	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	A1	C3	Exam 1	60	E41	1	1	1	0	40	30	30	0	100
34	4	A1	C3	Exam 2	60	E41	1	1	1	0	40	30	30	0	100
35	4	A1	C3	Exam 3	60	E41	1	1	1	0	40	30	30	0	100
36	4	A1	C3	Exam 4	60	E41	1	1	1	0	40	30	30	0	100
37	4	A1	C3	Exam 5	40	E42	1	1	1	0	40	30	30	0	100
38	4	A1	C3	Exam 6	40	E42	1	1	1	0	40	30	30	0	100
39	4	A1	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	A1	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c·CC_1$	$w_c·CC_2$	$w_c·CC_3$	$w_c·CC_4$	A. Grade
41	5	A1	PLS	Session01	100	L11	1	0	0	1	20	0	0	80	100
42	5	A1	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	A1	PLS	Session03	100	L11	1	0	0	0	20	0	0	0	20
44	5	A1	PLS	Session04	100	L11	1	0	0	1	20	0	0	80	100
45	5	A1	PLS	Session05	100	L11	0	0	0	1	0	0	0	80	80
46	5	A1	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	A1	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	A1	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	A1	PLS	Session09	100	L11	1	0	0	1	20	0	0	80	100
50	5	A1	PLS	Session10	100	L11	1	0	0	1	20	0	0	80	100
51	5	A1	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	A1	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	A1	PLS	Session13	100	L11	0	0	0	1	0	0	0	80	80
54	5	A1	PLS	Session14	100	L11	1	0	0	1	20	0	0	80	100
55	5	A1	PLS	Session15	100	L11	1	0	0	1	20	0	0	80	100
56	5	A1	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	A1	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	A1	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	A1	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	A1	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	A1	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	A1	PLS	Session22	100	L11	1	0	0	1	20	0	0	80	100
63	5	A1	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	A1	PLS	Session24	100	L11	1	0	0	1	20	0	0	80	100
65	5	A1	PLS	Session25	100	L11	1	0	0	1	20	0	0	80	100
66	5	A1	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	A1	PLS	Session27	100	L11	1	0	0	1	20	0	0	80	100
68	5	A1	PL1	ExLab1	100	L21	0	0	0	1	0	0	0	60	60
69	5	A1	PL2	ExLab2	100	L31	1	1	1	1	20	10	10	60	100
70	5	A1	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c·CC_1$	$w_c·CC_2$	$w_c·CC_3$	$w_c·CC_4$	A. Grade
71	6	A1	TA1	Task1	100	T11	1	0	1	1	30	0	20	30	80
72	6	A1	TA2	Task2	100	T21	1	0	1	1	30	0	20	30	80

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c·CC_1$	$w_c·CC_2$	$w_c·CC_3$	$w_c·CC_4$	A. Grade
73	7	A1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	A1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	A1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	A1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	A1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	A1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
79	7	A1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
80	7	A1	Retro	A	40	E32	1	1	1	0	40	30	30	0	100
81	7	A1	Retro	A	40	E32	1	1	1	0	40	30	30	0	100

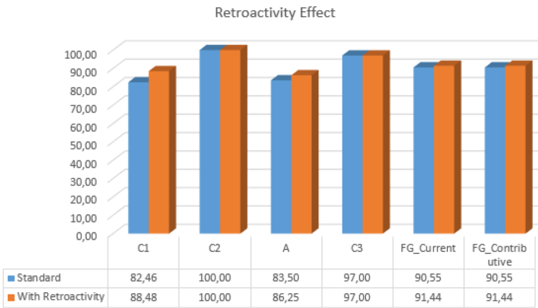
» ATC cuboid before retroactivity effect

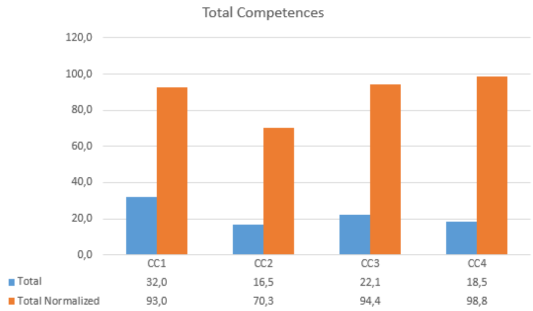
										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						82,5	100,0	83,5	97,0	87,5	80,0	90,6	90,6
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	8	8	8	0	48.000	24.000	8.000	0	40,0	20,0	6,7	0,0	66,7
C1	90	Exam	E1	6	190	5	5	5	0	6.400	4.800	4.800	0	33,7	25,3	25,3	0,0	84,2
C2	100	Exam	E2	7	400	7	7	7	0	16.000	12.000	12.000	0	40,0	30,0	30,0	0,0	100,0
A	100	Exam	E3	7	400	7	3	7	0	16.000	5.400	12.000	0	40,0	13,5	30,0	0,0	83,5
C3	100	Exam	E4	8	400	8	8	7	0	16.000	12.000	10.800	0	40,0	30,0	27,0	0,0	97,0
PL	30	Lab	L1	27	2.700	25	0	0	26	50.000	0	0	208.000	18,5	0,0	0,0	77,0	95,6
PL	28	Exam	L2	1	100	0	0	0	1	0	0	0	6.000	0,0	0,0	0,0	60,0	60,0
PL	42	Exam	L3	2	200	2	2	2	2	4.000	2.000	2.000	12.000	20,0	10,0	10,0	60,0	100,0
T	50	Assig	T1	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
T	50	Assig	T2	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
					#Positive CC evaluations	64	33	38	31	162.400	60.200	53.600	232.000					
					Efectiveness	88,9	73,3	84,4	96,9									

» ATC cuboid after retroactivity effect

										Grades	**C1**	**C2**	**A**	**C3**	**PL**	**T**	**FCG**	**FG**
MoE:	7	**Start:**	1	**End:**	81						**88,5**	**100,0**	**86,3**	**97,0**	**87,5**	**80,0**	**91,4**	**91,4**
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	8	8	8	0	48.000	24.000	8.000	0	40,0	20,0	6,7	0,0	66,7
C1	90	Exam	E1	10	330	9	9	9	0	12.000	9.000	9.000	0	36,4	27,3	27,3	0,0	90,9
C2	100	Exam	E2	10	520	10	10	10	0	20.800	15.600	15.600	0	40,0	30,0	30,0	0,0	100,0
A	100	Exam	E3	9	480	9	5	9	0	19.200	7.800	14.400	0	40,0	16,3	30,0	0,0	86,3
C3	100	Exam	E4	8	400	8	8	7	0	16.000	12.000	10.800	0	40,0	30,0	27,0	0,0	97,0
PL	30	Lab	L1	27	2.700	25	0	0	26	50.000	0	0	208.000	18,5	0,0	0,0	77,0	95,6
PL	28	Exam	L2	1	100	0	0	0	1	0	0	0	6.000	0,0	0,0	0,0	60,0	60,0
PL	42	Exam	L3	2	200	2	2	2	2	4.000	2.000	2.000	12.000	20,0	10,0	10,0	60,0	100,0
T	50	Assig	T1	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
T	50	Assig	T2	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
					#Positive CC evaluations	73	42	47	31	176.000	70.400	63.800	232.000					
					Efectiveness	90,1	77,8	87,0	96,9									

» Graphic results





I.2 Student A2

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	A2	C1	Test 1	100	P11	1	1	1	0	60	30	10	0	100
2	1	A2	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	A2	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	A2	C1	Test 4	100	P11	1	1	1	0	60	30	10	0	100
5	1	A2	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	A2	C1	Test 6	100	P11	1	1	1	0	60	30	10	0	100
7	1	A2	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	A2	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	A2	C1	Test 9	100	P11	1	1	1	0	60	30	10	0	100
10	1	A2	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	A2	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	A2	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	A2	C1	Exam 1	30	E11	1	1	1	0	40	30	30	0	100
14	1	A2	C1	Exam 2	30	E12	1	1	1	0	40	30	30	0	100
15	1	A2	C1	Exam 3	30	E11	1	1	1	0	40	30	30	0	100
16	1	A2	C1	Exam 4	40	E13	1	1	1	0	40	30	30	0	100
17	1	A2	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	A2	C1	Exam 6	30	E11	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	A2	C2	Exam 1	60	E21	0	1	1	0	0	30	30	0	60
20	2	A2	C2	Exam 2	60	E21	1	1	1	0	40	30	30	0	100
21	2	A2	C2	Exam 3	60	E21	1	1	1	0	40	30	30	0	100
22	2	A2	C2	Exam 4	40	E22	1	1	1	0	40	30	30	0	100
23	2	A2	C2	Exam 5	60	E21	0	1	1	0	0	30	30	0	60
24	2	A2	C2	Exam 6	60	E21	1	0	1	0	40	0	30	0	70
25	2	A2	C2	Exam 7	60	E21	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	A2	A	Exam 1	60	E31	1	1	1	0	40	30	30	0	100
27	3	A2	A	Exam 2	40	E32	0	1	1	0	0	30	30	0	60
28	3	A2	A	Exam 3	60	E31	0	1	1	0	0	30	30	0	60
29	3	A2	A	Exam 4	60	E31	1	1	1	0	40	30	30	0	100
30	3	A2	A	Exam 5	60	E31	1	1	1	0	40	30	30	0	100
31	3	A2	A	Exam 6	60	E31	1	1	1	0	40	30	30	0	100
32	3	A2	A	Exam 7	60	E31	1	0	1	0	40	0	30	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	A2	C3	Exam 1	60	E41	1	1	1	0	40	30	30	0	100
34	4	A2	C3	Exam 2	60	E41	1	1	0	0	40	30	0	0	70
35	4	A2	C3	Exam 3	60	E41	1	1	1	0	40	30	30	0	100
36	4	A2	C3	Exam 4	60	E41	1	1	1	0	40	30	30	0	100
37	4	A2	C3	Exam 5	40	E42	1	1	1	0	40	30	30	0	100
38	4	A2	C3	Exam 6	40	E42	1	1	1	0	40	30	30	0	100
39	4	A2	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	A2	C3	Exam 8	40	E43	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	A2	PLS	Session01	100	L11	0	0	0	1	0	0	0	80	80
42	5	A2	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	A2	PLS	Session03	100	L11	1	0	0	1	20	0	0	80	100
44	5	A2	PLS	Session04	100	L11	1	0	0	1	20	0	0	80	100
45	5	A2	PLS	Session05	100	L11	1	0	0	1	20	0	0	80	100
46	5	A2	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	A2	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	A2	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	A2	PLS	Session09	100	L11	1	0	0	1	20	0	0	80	100
50	5	A2	PLS	Session10	100	L11	1	0	0	1	20	0	0	80	100
51	5	A2	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	A2	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	A2	PLS	Session13	100	L11	1	0	0	1	20	0	0	80	100
54	5	A2	PLS	Session14	100	L11	1	0	0	1	20	0	0	80	100
55	5	A2	PLS	Session15	100	L11	1	0	0	1	20	0	0	80	100
56	5	A2	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	A2	PLS	Session17	100	L11	0	0	0	1	0	0	0	80	80
58	5	A2	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	A2	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	A2	PLS	Session20	100	L11	0	0	0	0	0	0	0	0	0
61	5	A2	PLS	Session21	100	L11	0	0	0	1	0	0	0	80	80
62	5	A2	PLS	Session22	100	L11	1	0	0	1	20	0	0	80	100
63	5	A2	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	A2	PLS	Session24	100	L11	1	0	0	1	20	0	0	80	100
65	5	A2	PLS	Session25	100	L11	1	0	0	1	20	0	0	80	100
66	5	A2	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	A2	PLS	Session27	100	L11	1	0	0	1	20	0	0	80	100
68	5	A2	PL1	ExLab1	100	L21	0	1	0	1	0	10	0	60	70
69	5	A2	PL2	ExLab2	100	L31	1	1	1	1	20	10	10	60	100
70	5	A2	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	A2	TA1	Task1	100	T11	0	1	1	1	0	20	20	30	70
72	6	A2	TA2	Task2	100	T21	1	1	1	1	30	20	20	30	100

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	A2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	A2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	A2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	A2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	A2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	A2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
79	7	A2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
80	7	A2	Retro	A	40	E32	1	1	1	0	40	30	30	0	100
81	7	A2	Retro	A	40	E32	1	1	1	0	40	30	30	0	100
82	7	A2	Retro	A	40	E32	1	1	1	0	40	30	30	0	100

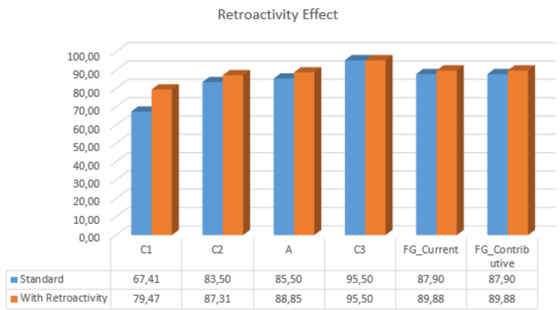
» ATC cuboid before retroactivity effect

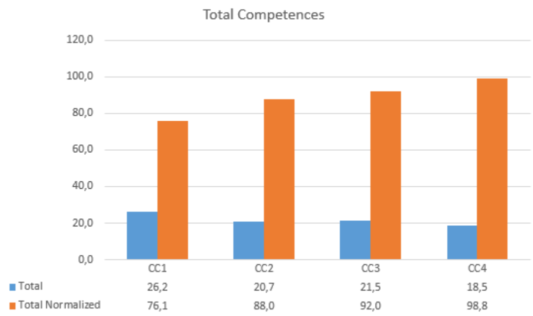
										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						67,4	83,5	85,5	95,5	89,8	85,0	87,9	87,9
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	7	7	7	0	42.000	21.000	7.000	0	35,0	17,5	5,8	0,0	58,3
C1	90	Exam	E1	6	190	4	4	4	0	5.200	3.900	3.900	0	27,4	20,5	20,5	0,0	68,4
C2	100	Exam	E2	7	400	5	6	7	0	11.200	10.200	12.000	0	28,0	25,5	30,0	0,0	83,5
A	100	Exam	E3	7	400	5	6	7	0	12.000	10.200	12.000	0	30,0	25,5	30,0	0,0	85,5
C3	100	Exam	E4	8	400	8	8	7	0	16.000	12.000	10.200	0	40,0	30,0	25,5	0,0	95,5
PL	30	Lab	L1	27	2.700	23	0	0	26	46.000	0	0	208.000	17,0	0,0	0,0	77,0	94,1
PL	28	Exam	L2	1	100	0	1	0	1	0	1.000	0	6.000	0,0	10,0	0,0	60,0	70,0
PL	42	Exam	L3	2	200	2	2	2	2	4.000	2.000	2.000	12.000	20,0	10,0	10,0	60,0	100,0
T	50	Assig	T1	1	100	0	1	1	1	0	2.000	2.000	3.000	0,0	20,0	20,0	30,0	70,0
T	50	Assig	T2	1	100	1	1	1	1	3.000	2.000	2.000	3.000	30,0	20,0	20,0	30,0	100,0
					#Positive CC evaluations	55	36	36	31	139.400	64.300	51.100	232.000					
					Efectiveness	76,4	80,0	80,0	96,9									

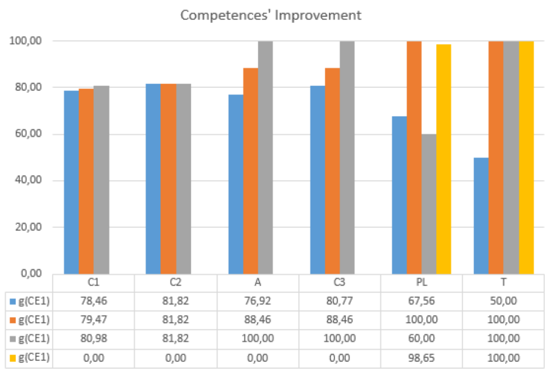
» ATC cuboid after retroactivity effect

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	7	**Start:**	1	**End:**	82						79,5	87,3	88,8	95,5	89,8	85,0	89,9	89,9
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	7	7	7	0	42.000	21.000	7.000	0	35,0	17,5	5,8	0,0	58,3
C1	90	Exam	E1	10	330	8	8	8	0	10.800	8.100	8.100	0	32,7	24,5	24,5	0,0	81,8
C2	100	Exam	E2	10	520	8	9	10	0	16.000	13.800	15.600	0	30,8	26,5	30,0	0,0	87,3
A	100	Exam	E3	10	520	8	9	10	0	16.800	13.800	15.600	0	32,3	26,5	30,0	0,0	88,8
C3	100	Exam	E4	8	400	8	8	7	0	16.000	12.000	10.200	0	40,0	30,0	25,5	0,0	95,5
PL	30	Lab	L1	27	2.700	23	0	0	26	46.000	0	0	208.000	17,0	0,0	0,0	77,0	94,1
PL	28	Exam	L2	1	100	0	1	0	1	0	1.000	0	6.000	0,0	10,0	0,0	60,0	70,0
PL	42	Exam	L3	2	200	2	2	2	2	4.000	2.000	2.000	12.000	20,0	10,0	10,0	60,0	100,0
T	50	Assig	T1	1	100	0	1	1	1	0	2.000	2.000	3.000	0,0	20,0	20,0	30,0	70,0
T	50	Assig	T2	1	100	1	1	1	1	3.000	2.000	2.000	3.000	30,0	20,0	20,0	30,0	100,0
					#Positive CC evaluations	65	46	46	31	154.600	75.700	62.500	232.000					
					Efectiveness	79,3	83,6	83,6	96,9									

» Graphic results







I.3 Student C1

It has been used to develop the ATC method in Chapter 6.

I.4 Student C2

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	C2	C1	Test 1	100	P11	1	1	1	0	60	30	10	0	100
2	1	C2	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	C2	C1	Test 3	100	P11	0	0	0	0	0	0	0	0	0
4	1	C2	C1	Test 4	100	P11	1	1	1	0	60	30	10	0	100
5	1	C2	C1	Test 5	100	P11	1	1	1	0	60	30	10	0	100
6	1	C2	C1	Test 6	100	P11	1	1	1	0	60	30	10	0	100
7	1	C2	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	C2	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	C2	C1	Test 9	100	P11	0	0	0	0	0	0	0	0	0
10	1	C2	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	C2	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	C2	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	C2	C1	Exam 1	30	E11	0	0	0	0	0	0	0	0	0
14	1	C2	C1	Exam 2	30	E12	0	0	0	0	0	0	0	0	0
15	1	C2	C1	Exam 3	30	E11	1	1	1	0	40	30	30	0	100
16	1	C2	C1	Exam 4	40	E13	0	0	0	0	0	0	0	0	0
17	1	C2	C1	Exam 5	30	E11	0	1	1	0	0	30	30	0	60
18	1	C2	C1	Exam 6	30	E11	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	C2	C2	Exam 1	60	E21	1	1	1	0	40	30	30	0	100
20	2	C2	C2	Exam 2	60	E21	1	1	1	0	40	30	30	0	100
21	2	C2	C2	Exam 3	60	E21	0	1	1	0	0	30	30	0	60
22	2	C2	C2	Exam 4	40	E22	1	1	1	0	40	30	30	0	100
23	2	C2	C2	Exam 5	60	E21	0	0	0	0	0	0	0	0	0
24	2	C2	C2	Exam 6	60	E21	1	1	1	0	40	30	30	0	100
25	2	C2	C2	Exam 7	60	E21	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	C2	A	Exam 1	60	E31	1	1	0	0	40	30	0	0	70
27	3	C2	A	Exam 2	40	E32	1	1	1	0	40	30	30	0	100
28	3	C2	A	Exam 3	60	E31	1	1	1	0	40	30	30	0	100
29	3	C2	A	Exam 4	60	E31	1	0	1	0	40	0	30	0	70
30	3	C2	A	Exam 5	60	E31	1	1	1	0	40	30	30	0	100
31	3	C2	A	Exam 6	60	E31	1	1	1	0	40	30	30	0	100
32	3	C2	A	Exam 7	60	E31	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	C2	C3	Exam 1	60	E41	0	0	1	0	0	0	30	0	30
34	4	C2	C3	Exam 2	60	E41	1	0	1	0	40	0	30	0	70
35	4	C2	C3	Exam 3	60	E41	1	1	1	0	40	30	30	0	100
36	4	C2	C3	Exam 4	60	E41	1	1	0	0	40	30	0	0	70
37	4	C2	C3	Exam 5	40	E42	1	1	1	0	40	30	30	0	100
38	4	C2	C3	Exam 6	40	E42	1	1	1	0	40	30	30	0	100
39	4	C2	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	C2	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	C2	PLS	Session01	100	L11	1	0	0	1	20	0	0	80	100
42	5	C2	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	C2	PLS	Session03	100	L11	0	0	0	1	0	0	0	80	80
44	5	C2	PLS	Session04	100	L11	0	0	0	1	0	0	0	80	80
45	5	C2	PLS	Session05	100	L11	0	0	0	0	0	0	0	0	0
46	5	C2	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	C2	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	C2	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	C2	PLS	Session09	100	L11	1	0	0	1	20	0	0	80	100
50	5	C2	PLS	Session10	100	L11	0	0	0	1	0	0	0	80	80
51	5	C2	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	C2	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	C2	PLS	Session13	100	L11	0	0	0	0	0	0	0	0	0
54	5	C2	PLS	Session14	100	L11	0	0	0	0	0	0	0	0	0
55	5	C2	PLS	Session15	100	L11	0	0	0	1	0	0	0	80	80
56	5	C2	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	C2	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	C2	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	C2	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	C2	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	C2	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	C2	PLS	Session22	100	L11	1	0	0	1	20	0	0	80	100
63	5	C2	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	C2	PLS	Session24	100	L11	0	0	0	1	0	0	0	80	80
65	5	C2	PLS	Session25	100	L11	1	0	0	1	20	0	0	80	100
66	5	C2	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	C2	PLS	Session27	100	L11	1	0	0	1	20	0	0	80	100
68	5	C2	PL1	ExLab1	100	L21	0	1	1	0	0	10	10	0	20
69	5	C2	PL2	ExLab2	100	L31	0	0	0	1	0	0	0	60	60
70	5	C2	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	C2	TA1	Task1	100	T11	1	0	1	1	30	0	20	30	80
72	6	C2	TA2	Task2	100	T21	1	0	0	1	30	0	0	30	60

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CC_2	CC_3	CC_4	$w_c \cdot CC_1$	$w_c \cdot CC_2$	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	C2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	C2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	C2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	C2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	C2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	C2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
79	7	C2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
80	7	C2	Retro	A	40	E32	1	1	1	0	40	30	30	0	100
81	7	C2	Retro	A	40	E32	1	1	1	0	40	30	30	0	100

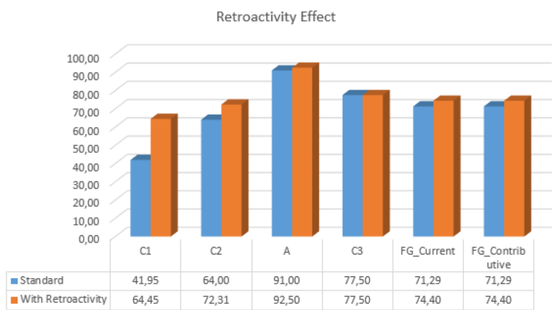
» ATC cuboid before retroactivity effect

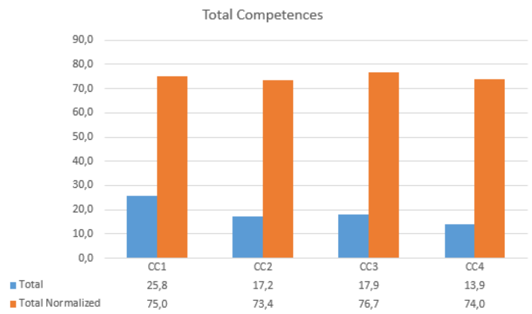
										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						41,9	64,0	91,0	77,5	64,8	70,0	71,3	71,3
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	6	6	6	0	36.000	18.000	6.000	0	30,0	15,0	5,0	0,0	50,0
C1	90	Exam	E1	6	190	2	3	3	0	2.400	2.700	2.700	0	12,6	14,2	14,2	0,0	41,1
C2	100	Exam	E2	7	400	4	5	5	0	8.800	8.400	8.400	0	22,0	21,0	21,0	0,0	64,0
A	100	Exam	E3	7	400	7	6	6	0	16.000	10.200	10.200	0	40,0	25,5	25,5	0,0	91,0
C3	100	Exam	E4	8	400	7	6	6	0	13.600	8.400	9.000	0	34,0	21,0	22,5	0,0	77,5
PL	30	Lab	L1	27	2.700	19	0	0	24	38.000	0	0	192.000	14,1	0,0	0,0	71,1	85,2
PL	28	Exam	L2	1	100	0	1	1	0	0	1.000	1.000	0	0,0	10,0	10,0	0,0	20,0
PL	42	Exam	L3	2	200	1	1	1	2	2.000	1.000	1.000	12.000	10,0	5,0	5,0	60,0	80,0
T	50	Assig	T1	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
T	50	Assig	T2	1	100	1	0	0	1	3.000	0	0	3.000	30,0	0,0	0,0	30,0	60,0
					#Positive CC evaluations	48	28	29	28	122.800	49.700	40.300	210.000					
					Efectiveness	66,7	62,2	64,4	87,5									

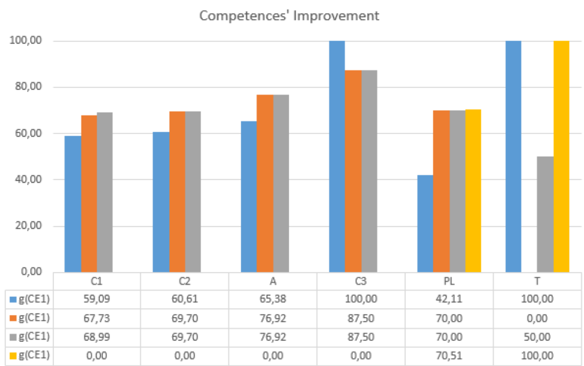
» ATC cuboid after retroactivity effect

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	7	Start:	1	End:	81						64,5	72,3	92,5	77,5	64,8	70,0	74,4	74,4
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	6	6	6	0	36.000	18.000	6.000	0	30,0	15,0	5,0	0,0	50,0
C1	90	Exam	E1	10	330	6	7	7	0	8.000	6.900	6.900	0	24,2	20,9	20,9	0,0	66,1
C2	100	Exam	E2	10	520	7	8	8	0	13.600	12.000	12.000	0	26,2	23,1	23,1	0,0	72,3
A	100	Exam	E3	9	480	9	8	8	0	19.200	12.600	12.600	0	40,0	26,3	26,3	0,0	92,5
C3	100	Exam	E4	8	400	7	6	6	0	13.600	8.400	9.000	0	34,0	21,0	22,5	0,0	77,5
PL	30	Lab	L1	27	2.700	19	0	0	24	38.000	0	0	192.000	14,1	0,0	0,0	71,1	85,2
PL	28	Exam	L2	1	100	0	1	1	0	0	1.000	1.000	0	0,0	10,0	10,0	0,0	20,0
PL	42	Exam	L3	2	200	1	1	1	2	2.000	1.000	1.000	12.000	10,0	5,0	5,0	60,0	80,0
T	50	Assig	T1	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
T	50	Assig	T2	1	100	1	0	0	1	3.000	0	0	3.000	30,0	0,0	0,0	30,0	60,0
					#Positive CC evaluations	57	37	38	28	136.400	59.900	50.500	210.000					
					Efectiveness	70,4	68,5	70,4	87,5									

» Graphic results







I.5 Student D1

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	D1	C1	Test 1	100	P11	1	1	1	0	60	30	10	0	100
2	1	D1	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	D1	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	D1	C1	Test 4	100	P11	0	0	0	0	0	0	0	0	0
5	1	D1	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	D1	C1	Test 6	100	P11	1	1	1	0	60	30	10	0	100
7	1	D1	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	D1	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	D1	C1	Test 9	100	P11	0	0	0	0	0	0	0	0	0
10	1	D1	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	D1	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	D1	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	D1	C1	Exam 1	30	E11	1	1	1	0	40	30	30	0	100
14	1	D1	C1	Exam 2	30	E12	1	0	0	0	40	0	0	0	40
15	1	D1	C1	Exam 3	30	E11	0	0	0	0	0	0	0	0	0
16	1	D1	C1	Exam 4	40	E13	0	0	0	0	0	0	0	0	0
17	1	D1	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	D1	C1	Exam 6	30	E11	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	D1	C2	Exam 1	60	E21	1	0	1	0	40	0	30	0	70
20	2	D1	C2	Exam 2	60	E21	1	1	1	0	40	30	30	0	100
21	2	D1	C2	Exam 3	60	E21	1	0	1	0	40	0	30	0	70
22	2	D1	C2	Exam 4	40	E22	1	1	1	0	40	30	30	0	100
23	2	D1	C2	Exam 5	60	E21	0	1	1	0	0	30	30	0	60
24	2	D1	C2	Exam 6	60	E21	1	0	1	0	40	0	30	0	70
25	2	D1	C2	Exam 7	60	E21	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	D1	A	Exam 1	60	E31	1	1	0	0	40	30	0	0	70
27	3	D1	A	Exam 2	40	E32	1	1	0	0	40	30	0	0	70
28	3	D1	A	Exam 3	60	E31	1	1	0	0	40	30	0	0	70
29	3	D1	A	Exam 4	60	E31	1	0	1	0	40	0	30	0	70
30	3	D1	A	Exam 5	60	E31	1	1	1	0	40	30	30	0	100
31	3	D1	A	Exam 6	60	E31	1	1	0	0	40	30	0	0	70
32	3	D1	A	Exam 7	60	E31	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	D1	C3	Exam 1	60	E41	1	0	1	0	40	0	30	0	70
34	4	D1	C3	Exam 2	60	E41	0	0	1	0	0	0	30	0	30
35	4	D1	C3	Exam 3	60	E41	1	0	0	0	40	0	0	0	40
36	4	D1	C3	Exam 4	60	E41	1	0	1	0	40	0	30	0	70
37	4	D1	C3	Exam 5	40	E42	1	0	0	0	40	0	0	0	40
38	4	D1	C3	Exam 6	40	E42	1	1	0	0	40	30	0	0	70
39	4	D1	C3	Exam 7	40	E43	1	0	0	0	40	0	0	0	40
40	4	D1	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	D1	PLS	Session01	100	L11	0	0	0	1	0	0	0	80	80
42	5	D1	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	D1	PLS	Session03	100	L11	1	0	0	1	20	0	0	80	100
44	5	D1	PLS	Session04	100	L11	0	0	0	1	0	0	0	80	80
45	5	D1	PLS	Session05	100	L11	1	0	0	1	20	0	0	80	100
46	5	D1	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	D1	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	D1	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	D1	PLS	Session09	100	L11	1	0	0	0	20	0	0	0	20
50	5	D1	PLS	Session10	100	L11	1	0	0	1	20	0	0	80	100
51	5	D1	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	D1	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	D1	PLS	Session13	100	L11	1	0	0	1	20	0	0	80	100
54	5	D1	PLS	Session14	100	L11	1	0	0	1	20	0	0	80	100
55	5	D1	PLS	Session15	100	L11	0	0	0	1	0	0	0	80	80
56	5	D1	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	D1	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	D1	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	D1	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	D1	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	D1	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	D1	PLS	Session22	100	L11	1	0	0	1	20	0	0	80	100
63	5	D1	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	D1	PLS	Session24	100	L11	1	0	0	1	20	0	0	80	100
65	5	D1	PLS	Session25	100	L11	0	0	0	1	0	0	0	80	80
66	5	D1	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	D1	PLS	Session27	100	L11	1	0	0	1	20	0	0	80	100
68	5	D1	PL1	ExLab1	100	L21	1	0	0	0	20	0	0	0	20
69	5	D1	PL2	ExLab2	100	L31	1	1	1	0	20	10	10	0	40
70	5	D1	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	D1	TA1	Task1	100	T11	0	1	1	1	0	20	20	30	70
72	6	D1	TA2	Task2	100	T21	1	0	1	1	30	0	20	30	80

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	D1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	D1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	D1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	D1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	D1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	D1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100

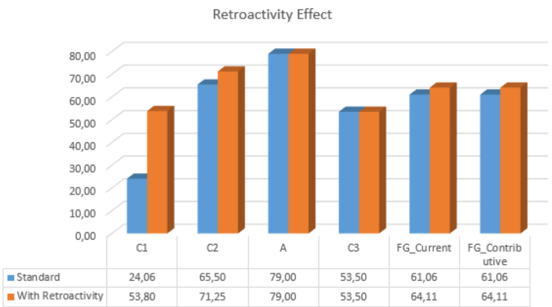
» ATC cuboid before retroactivity effect

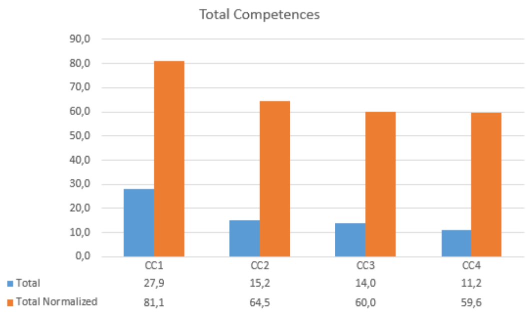
										Grades	**C1**	**C2**	**A**	**C3**	**PL**	**T**	**FCG**	**FG**
MoE:	6	**Start:**	1	**End:**	72						**24,1**	**65,5**	**79,0**	**53,5**	**63,2**	**75,0**	**61,1**	**61,1**
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	5	5	5	0	30.000	15.000	5.000	0	25,0	12,5	4,2	0,0	41,7
C1	90	Exam	E1	6	190	2	1	1	0	2.400	900	900	0	12,6	4,7	4,7	0,0	22,1
C2	100	Exam	E2	7	400	5	3	6	0	11.200	4.800	10.200	0	28,0	12,0	25,5	0,0	65,5
A	100	Exam	E3	7	400	7	6	3	0	16.000	10.200	5.400	0	40,0	25,5	13,5	0,0	79,0
C3	100	Exam	E4	8	400	7	2	3	0	13.600	2.400	5.400	0	34,0	6,0	13,5	0,0	53,5
PL	30	Lab	L1	27	2.700	23	0	0	26	46.000	0	0	208.000	17,0	0,0	0,0	77,0	94,1
PL	28	Exam	L2	1	100	1	0	0	0	2.000	0	0	0	20,0	0,0	0,0	0,0	20,0
PL	42	Exam	L3	2	200	2	2	2	1	4.000	2.000	2.000	6.000	20,0	10,0	10,0	30,0	70,0
T	50	Assig	T1	1	100	0	1	1	1	0	2.000	2.000	3.000	0,0	20,0	20,0	30,0	70,0
T	50	Assig	T2	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
					#Positive CC evaluations	53	20	22	29	128.200	37.300	32.900	220.000					
					Efectiveness	73,6	44,4	48,9	90,6									

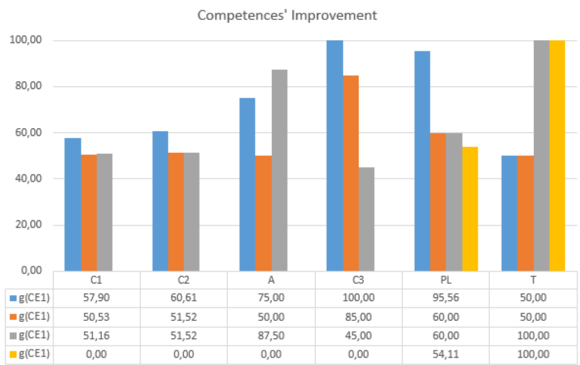
» ATC cuboid after retroactivity effect

										Grades	**C1**	**C2**	**A**	**C3**	**PL**	**T**	**FCG**	**FG**
MoE:	7	**Start:**	1	**End:**	78						**53,8**	**71,3**	**79,0**	**53,5**	**63,2**	**75,0**	**64,1**	**64,1**
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**$D=\sum W_A$**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	5	5	5	0	30.000	15.000	5.000	0	25,0	12,5	4,2	0,0	41,7
C1	90	Exam	E1	10	330	6	5	5	0	8.000	5.100	5.100	0	24,2	15,5	15,5	0,0	55,2
C2	100	Exam	E2	9	480	7	5	8	0	14.400	7.200	12.600	0	30,0	15,0	26,3	0,0	71,3
A	100	Exam	E3	7	400	7	6	3	0	16.000	10.200	5.400	0	40,0	25,5	13,5	0,0	79,0
C3	100	Exam	E4	8	400	7	2	3	0	13.600	2.400	5.400	0	34,0	6,0	13,5	0,0	53,5
PL	30	Lab	L1	27	2.700	23	0	0	26	46.000	0	0	208.000	17,0	0,0	0,0	77,0	94,1
PL	28	Exam	L2	1	100	1	0	0	0	2.000	0	0	0	20,0	0,0	0,0	0,0	20,0
PL	42	Exam	L3	2	200	2	2	2	1	4.000	2.000	2.000	6.000	20,0	10,0	10,0	30,0	70,0
T	50	Assig	T1	1	100	0	1	1	1	0	2.000	2.000	3.000	0,0	20,0	20,0	30,0	70,0
T	50	Assig	T2	1	100	1	0	1	1	3.000	0	2.000	3.000	30,0	0,0	20,0	30,0	80,0
					#Positive CC evaluations	59	26	28	29	137.000	43.900	39.500	220.000					
					Efectiveness	75,6	51,0	54,9	90,6									

» Graphic results







I.6 Student D2

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	D2	C1	Test 1	100	P11	0	0	0	0	0	0	0	0	0
2	1	D2	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	D2	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	D2	C1	Test 4	100	P11	0	0	0	0	0	0	0	0	0
5	1	D2	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	D2	C1	Test 6	100	P11	0	0	0	0	0	0	0	0	0
7	1	D2	C1	Test 7	100	P11	1	1	1	0	60	30	10	0	100
8	1	D2	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	D2	C1	Test 9	100	P11	1	1	1	0	60	30	10	0	100
10	1	D2	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	D2	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	D2	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	D2	C1	Exam 1	30	E11	1	1	1	0	40	30	30	0	100
14	1	D2	C1	Exam 2	30	E12	0	0	0	0	0	0	0	0	0
15	1	D2	C1	Exam 3	30	E11	0	0	0	0	0	0	0	0	0
16	1	D2	C1	Exam 4	40	E13	0	1	0	0	0	30	0	0	30
17	1	D2	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	D2	C1	Exam 6	30	E11	1	1	1	0	40	30	30	0	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	D2	C2	Exam 1	60	E21	1	1	1	0	40	30	30	0	100
20	2	D2	C2	Exam 2	60	E21	0	0	0	0	0	0	0	0	0
21	2	D2	C2	Exam 3	60	E21	0	0	0	0	0	0	0	0	0
22	2	D2	C2	Exam 4	40	E22	1	1	0	0	40	30	0	0	70
23	2	D2	C2	Exam 5	60	E21	0	0	0	0	0	0	0	0	0
24	2	D2	C2	Exam 6	60	E21	0	0	0	0	0	0	0	0	0
25	2	D2	C2	Exam 7	60	E21	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	D2	A	Exam 1	60	E31	1	1	0	0	40	30	0	0	70
27	3	D2	A	Exam 2	40	E32	0	0	0	0	0	0	0	0	0
28	3	D2	A	Exam 3	60	E31	1	0	0	0	40	0	0	0	40
29	3	D2	A	Exam 4	60	E31	1	1	0	0	40	30	0	0	70
30	3	D2	A	Exam 5	60	E31	1	1	1	0	40	30	30	0	100
31	3	D2	A	Exam 6	60	E31	1	1	0	0	40	30	0	0	70
32	3	D2	A	Exam 7	60	E31	1	1	0	0	40	30	0	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	D2	C3	Exam 1	60	E41	1	1	1	0	40	30	30	0	100
34	4	D2	C3	Exam 2	60	E41	1	0	1	0	40	0	30	0	70
35	4	D2	C3	Exam 3	60	E41	0	1	0	0	0	30	0	0	30
36	4	D2	C3	Exam 4	60	E41	1	1	0	0	40	30	0	0	70
37	4	D2	C3	Exam 5	40	E42	1	0	1	0	40	0	30	0	70
38	4	D2	C3	Exam 6	40	E42	1	0	1	0	40	0	30	0	70
39	4	D2	C3	Exam 7	40	E43	1	1	1	0	40	30	30	0	100
40	4	D2	C3	Exam 8	40	E43	1	1	0	0	40	30	0	0	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	D2	PLS	Session01	100	L11	1	0	0	1	20	0	0	80	100
42	5	D2	PLS	Session02	100	L11	0	0	0	1	0	0	0	80	80
43	5	D2	PLS	Session03	100	L11	1	0	0	1	20	0	0	80	100
44	5	D2	PLS	Session04	100	L11	1	0	0	1	20	0	0	80	100
45	5	D2	PLS	Session05	100	L11	1	0	0	0	20	0	0	0	20
46	5	D2	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	D2	PLS	Session07	100	L11	0	0	0	1	0	0	0	80	80
48	5	D2	PLS	Session08	100	L11	0	0	0	1	0	0	0	80	80
49	5	D2	PLS	Session09	100	L11	1	0	0	0	20	0	0	0	20
50	5	D2	PLS	Session10	100	L11	0	0	0	1	0	0	0	80	80
51	5	D2	PLS	Session11	100	L11	0	0	0	1	0	0	0	80	80
52	5	D2	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	D2	PLS	Session13	100	L11	0	0	0	1	0	0	0	80	80
54	5	D2	PLS	Session14	100	L11	1	0	0	1	20	0	0	80	100
55	5	D2	PLS	Session15	100	L11	0	0	0	1	0	0	0	80	80
56	5	D2	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	D2	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	D2	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	D2	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	D2	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	D2	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	D2	PLS	Session22	100	L11	0	0	0	1	0	0	0	80	80
63	5	D2	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	D2	PLS	Session24	100	L11	0	0	0	1	0	0	0	80	80
65	5	D2	PLS	Session25	100	L11	0	0	0	1	0	0	0	80	80
66	5	D2	PLS	Session26	100	L11	0	0	0	1	0	0	0	80	80
67	5	D2	PLS	Session27	100	L11	0	0	0	1	0	0	0	80	80
68	5	D2	PL1	ExLab1	100	L21	0	1	0	0	0	10	0	0	10
69	5	D2	PL2	ExLab2	100	L31	1	1	0	0	20	10	0	0	30
70	5	D2	PL2	ExLab2	100	L32	0	1	0	1	0	10	0	60	70

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	D2	TA1	Task1	100	T11	0	1	0	0	0	20	0	0	20
72	6	D2	TA2	Task2	100	T21	1	0	0	0	30	0	0	0	30

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CD2	CC_3	CC_4	$w_c \cdot CC_1$	wc·CD2	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	D2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	D2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	D2	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	D2	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	D2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
78	7	D2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100
79	7	D2	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100

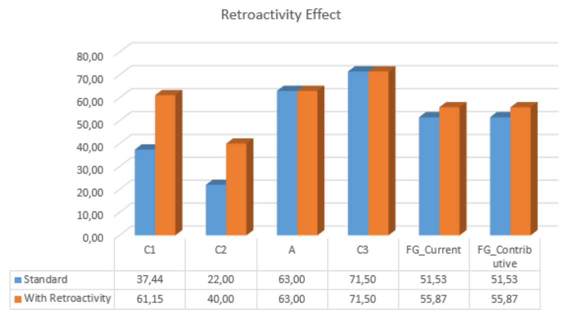
» ATC cuboid before retroactivity effect

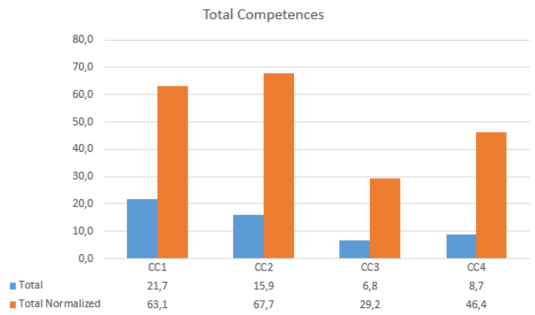
										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						37,4	22,0	63,0	71,5	49,4	25,0	51,5	51,5
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	4	4	4	0	24.000	12.000	4.000	0	20,0	10,0	3,3	0,0	33,3
C1	90	Exam	E1	6	190	2	3	2	0	2.400	3.000	1.800	0	12,6	15,8	9,5	0,0	37,9
C2	100	Exam	E2	7	400	2	2	1	0	4.000	3.000	1.800	0	10,0	7,5	4,5	0,0	22,0
A	100	Exam	E3	7	400	6	5	1	0	14.400	9.000	1.800	0	36,0	22,5	4,5	0,0	63,0
C3	100	Exam	E4	8	400	7	5	5	0	13.600	7.800	7.200	0	34,0	19,5	18,0	0,0	71,5
PL	30	Lab	L1	27	2.700	15	0	0	25	30.000	0	0	200.000	11,1	0,0	0,0	74,1	85,2
PL	28	Exam	L2	1	100	0	1	0	0	0	1.000	0	0	0,0	10,0	0,0	0,0	10,0
PL	42	Exam	L3	2	200	1	2	0	1	2.000	2.000	0	6.000	10,0	10,0	0,0	30,0	50,0
T	50	Assig	T1	1	100	0	1	0	0	0	2.000	0	0	0,0	20,0	0,0	0,0	20,0
T	50	Assig	T2	1	100	1	0	0	0	3.000	0	0	0	30,0	0,0	0,0	0,0	30,0
					#Positive CC evaluations	38	23	13	26	93.400	39.800	16.600	206.000					
					Efectiveness	52,8	51,1	28,9	81,3									

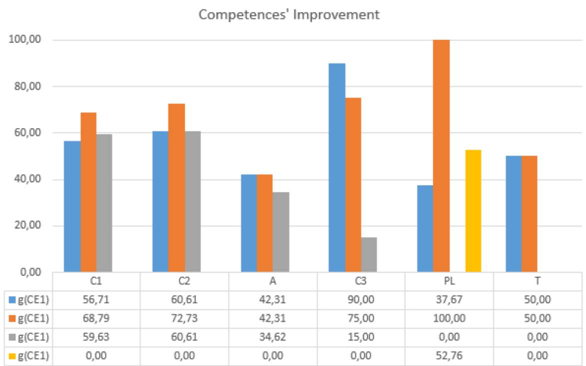
» ATC cuboid after retroactivity effect

										Grades	**C1**	**C2**	**A**	**C3**	**PL**	**T**	**FCG**	**FG**
MoE:	7	**Start:**	1	**End:**	79						**61,2**	**40,0**	**63,0**	**71,5**	**49,4**	**25,0**	**55,9**	**55,9**
Topic	**Weight**	**Activity**	**Subclass**	**#Act**	**D=∑W_A**	**SCC_1**	**SCC_2**	**SCC_3**	**SCC_4**	**$wSCC_1$**	**$wSCC_2$**	**$wSCC_3$**	**$wSCC_4$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**$g(CC_1)$**	**g(At)**
C1	10	Test	P1	12	1.200	4	4	4	0	24.000	12.000	4.000	0	20,0	10,0	3,3	0,0	33,3
C1	90	Exam	E1	10	330	6	7	6	0	8.000	7.200	6.000	0	24,2	21,8	18,2	0,0	64,2
C2	100	Exam	E2	10	520	5	5	4	0	8.800	6.600	5.400	0	16,9	12,7	10,4	0,0	40,0
A	100	Exam	E3	7	400	6	5	1	0	14.400	9.000	1.800	0	36,0	22,5	4,5	0,0	63,0
C3	100	Exam	E4	8	400	7	5	5	0	13.600	7.800	7.200	0	34,0	19,5	18,0	0,0	71,5
PL	30	Lab	L1	27	2.700	15	0	0	25	30.000	0	0	200.000	11,1	0,0	0,0	74,1	85,2
PL	28	Exam	L2	1	100	0	1	0	0	0	1.000	0	0	0,0	10,0	0,0	0,0	10,0
PL	42	Exam	L3	2	200	1	2	0	1	2.000	2.000	0	6.000	10,0	10,0	0,0	30,0	50,0
T	50	Assig	T1	1	100	0	1	0	0	0	2.000	0	0	0,0	20,0	0,0	0,0	20,0
T	50	Assig	T2	1	100	1	0	0	0	3.000	0	0	0	30,0	0,0	0,0	0,0	30,0
					#Positive CC evaluations	45	30	20	26	103.800	47.600	24.400	206.000					
					Efectiveness	57,0	57,7	38,5	81,3									

» Graphic results







I.7 Student F

» Activities backlog

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
1	1	F1	C1	Test 1	100	P11	1	1	1	0	60	30	10	0	100
2	1	F1	C1	Test 2	100	P11	1	1	1	0	60	30	10	0	100
3	1	F1	C1	Test 3	100	P11	1	1	1	0	60	30	10	0	100
4	1	F1	C1	Test 4	100	P11	0	0	0	0	0	0	0	0	0
5	1	F1	C1	Test 5	100	P11	0	0	0	0	0	0	0	0	0
6	1	F1	C1	Test 6	100	P11	1	1	1	0	60	30	10	0	100
7	1	F1	C1	Test 7	100	P11	0	0	0	0	0	0	0	0	0
8	1	F1	C1	Test 8	100	P11	0	0	0	0	0	0	0	0	0
9	1	F1	C1	Test 9	100	P11	0	0	0	0	0	0	0	0	0
10	1	F1	C1	Test 10	100	P11	0	0	0	0	0	0	0	0	0
11	1	F1	C1	Test 11	100	P11	0	0	0	0	0	0	0	0	0
12	1	F1	C1	Test 12	100	P11	0	0	0	0	0	0	0	0	0
13	1	F1	C1	Exam 1	30	E11	0	0	0	0	0	0	0	0	0
14	1	F1	C1	Exam 2	30	E12	0	0	0	0	0	0	0	0	0
15	1	F1	C1	Exam 3	30	E11	0	0	0	0	0	0	0	0	0
16	1	F1	C1	Exam 4	40	E13	0	0	0	0	0	0	0	0	0
17	1	F1	C1	Exam 5	30	E11	0	0	0	0	0	0	0	0	0
18	1	F1	C1	Exam 6	30	E11	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
19	2	F1	C2	Exam 1	60	E21	0	1	1	0	0	30	30	0	60
20	2	F1	C2	Exam 2	60	E21	0	0	0	0	0	0	0	0	0
21	2	F1	C2	Exam 3	60	E21	0	0	0	0	0	0	0	0	0
22	2	F1	C2	Exam 4	40	E22	0	1	1	0	0	30	30	0	60
23	2	F1	C2	Exam 5	60	E21	0	0	0	0	0	0	0	0	0
24	2	F1	C2	Exam 6	60	E21	0	1	1	0	0	30	30	0	60
25	2	F1	C2	Exam 7	60	E21	0	0	0	0	0	0	0	0	0

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
26	3	F1	A	Exam 1	60	E31	1	1	0	0	40	30	0	0	70
27	3	F1	A	Exam 2	40	E32	0	0	0	0	0	0	0	0	0
28	3	F1	A	Exam 3	60	E31	1	0	0	0	40	0	0	0	40
29	3	F1	A	Exam 4	60	E31	1	1	0	0	40	30	0	0	70
30	3	F1	A	Exam 5	60	E31	1	0	1	0	40	0	30	0	70
31	3	F1	A	Exam 6	60	E31	1	1	0	0	40	30	0	0	70
32	3	F1	A	Exam 7	60	E31	1	0	0	0	40	0	0	0	40

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
33	4	F1	C3	Exam 1	60	E41	0	0	1	0	0	0	30	0	30
34	4	F1	C3	Exam 2	60	E41	0	0	1	0	0	0	30	0	30
35	4	F1	C3	Exam 3	60	E41	0	0	0	0	0	0	0	0	0
36	4	F1	C3	Exam 4	60	E41	1	0	0	0	40	0	0	0	40
37	4	F1	C3	Exam 5	40	E42	1	0	0	0	40	0	0	0	40
38	4	F1	C3	Exam 6	40	E42	1	0	0	0	40	0	0	0	40
39	4	F1	C3	Exam 7	40	E43	1	0	0	0	40	0	0	0	40
40	4	F1	C3	Exam 8	40	E43	1	0	0	0	40	0	0	0	40

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
41	5	F1	PLS	Session01	100	L11	1	0	0	1	20	0	0	80	100
42	5	F1	PLS	Session02	100	L11	1	0	0	1	20	0	0	80	100
43	5	F1	PLS	Session03	100	L11	1	0	0	1	20	0	0	80	100
44	5	F1	PLS	Session04	100	L11	0	0	0	1	0	0	0	80	80
45	5	F1	PLS	Session05	100	L11	1	0	0	1	20	0	0	80	100
46	5	F1	PLS	Session06	100	L11	1	0	0	1	20	0	0	80	100
47	5	F1	PLS	Session07	100	L11	1	0	0	1	20	0	0	80	100
48	5	F1	PLS	Session08	100	L11	1	0	0	1	20	0	0	80	100
49	5	F1	PLS	Session09	100	L11	0	0	0	1	0	0	0	80	80
50	5	F1	PLS	Session10	100	L11	0	0	0	1	0	0	0	80	80
51	5	F1	PLS	Session11	100	L11	1	0	0	1	20	0	0	80	100
52	5	F1	PLS	Session12	100	L11	1	0	0	1	20	0	0	80	100
53	5	F1	PLS	Session13	100	L11	0	0	0	1	0	0	0	80	80
54	5	F1	PLS	Session14	100	L11	1	0	0	1	20	0	0	80	100
55	5	F1	PLS	Session15	100	L11	1	0	0	1	20	0	0	80	100
56	5	F1	PLS	Session16	100	L11	1	0	0	1	20	0	0	80	100
57	5	F1	PLS	Session17	100	L11	1	0	0	1	20	0	0	80	100
58	5	F1	PLS	Session18	100	L11	1	0	0	1	20	0	0	80	100
59	5	F1	PLS	Session19	100	L11	1	0	0	1	20	0	0	80	100
60	5	F1	PLS	Session20	100	L11	1	0	0	1	20	0	0	80	100
61	5	F1	PLS	Session21	100	L11	1	0	0	1	20	0	0	80	100
62	5	F1	PLS	Session22	100	L11	0	0	0	1	0	0	0	80	80
63	5	F1	PLS	Session23	100	L11	1	0	0	1	20	0	0	80	100
64	5	F1	PLS	Session24	100	L11	1	0	0	1	20	0	0	80	100
65	5	F1	PLS	Session25	100	L11	0	0	0	1	0	0	0	80	80
66	5	F1	PLS	Session26	100	L11	1	0	0	1	20	0	0	80	100
67	5	F1	PLS	Session27	100	L11	1	0	0	1	20	0	0	80	100
68	5	F1	PL1	ExLab1	100	L21	0	1	1	0	0	10	10	0	20
69	5	F1	PL2	ExLab2	100	L31	1	1	1	0	20	10	10	0	40
70	5	F1	PL2	ExLab2	100	L32	1	1	1	1	20	10	10	60	100

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
71	6	F1	TA1	Task1	100	T11	1	0	0	1	30	0	0	30	60
72	6	F1	TA2	Task2	100	T21	1	1	1	1	30	20	20	30	100

» Retroactivity executions

Act. N.	MoEv	Student	Topic	Activities	Weight	Subclass	CC_1	CF1	CC_3	CC_4	$w_c \cdot CC_1$	wc·CF1	$w_c \cdot CC_3$	$w_c \cdot CC_4$	A. Grade
73	7	F1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
74	7	F1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
75	7	F1	Retro	C1	30	E12	1	1	1	0	40	30	30	0	100
76	7	F1	Retro	C1	40	E13	1	1	1	0	40	30	30	0	100
77	7	F1	Retro	C2	40	E22	1	1	1	0	40	30	30	0	100

» ATC cuboid before retroactivity effect

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	6	Start:	1	End:	72						3,3	24,0	54,0	31,0	63,7	80,0	43,4	43,4
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	4	4	4	0	24.000	12.000	4.000	0	20,0	10,0	3,3	0,0	33,3
C1	90	Exam	E1	6	190	0	0	0	0	0	0	0	0	0,0	0,0	0,0	0,0	0,0
C2	100	Exam	E2	7	400	0	3	3	0	0	4.800	4.800	0	0,0	12,0	12,0	0,0	24,0
A	100	Exam	E3	7	400	6	3	1	0	14.400	5.400	1.800	0	36,0	13,5	4,5	0,0	54,0
C3	100	Exam	E4	8	400	5	0	2	0	8.800	0	3.600	0	22,0	0,0	9,0	0,0	31,0
PL	30	Lab	L1	27	2.700	21	0	0	27	42.000	0	0	216.000	15,6	0,0	0,0	80,0	95,6
PL	28	Exam	L2	1	100	0	1	1	0	0	1.000	1.000	0	0,0	10,0	10,0	0,0	20,0
PL	42	Exam	L3	2	200	2	2	2	1	4.000	2.000	2.000	6.000	20,0	10,0	10,0	30,0	70,0
T	50	Assig	T1	1	100	1	0	0	1	3.000	0	0	3.000	30,0	0,0	0,0	30,0	60,0
T	50	Assig	T2	1	100	1	1	1	1	3.000	2.000	2.000	3.000	30,0	20,0	20,0	30,0	100,0
					#Positive CC evaluations	40	14	14	30	99.200	27.200	19.200	228.000					
					Efectiveness	55,6	31,1	31,1	93,8									

» ATC cuboid after retroactivity effect

										Grades	C1	C2	A	C3	PL	T	FCG	FG
MoE:	7	Start:	1	End:	77						41,5	30,9	54,0	31,0	63,7	80,0	47,2	47,2
Topic	Weight	Activity	Subclass	#Act	$D=\sum W_A$	SCC_1	SCC_2	SCC_3	SCC_4	$wSCC_1$	$wSCC_2$	$wSCC_3$	$wSCC_4$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	$g(CC_1)$	g(At)
C1	10	Test	P1	12	1.200	4	4	4	0	24.000	12.000	4.000	0	20,0	10,0	3,3	0,0	33,3
C1	90	Exam	E1	10	330	4	4	4	0	5.600	4.200	4.200	0	17,0	12,7	12,7	0,0	42,4
C2	100	Exam	E2	8	440	1	4	4	0	1.600	6.000	6.000	0	3,6	13,6	13,6	0,0	30,9
A	100	Exam	E3	7	400	6	3	1	0	14.400	5.400	1.800	0	36,0	13,5	4,5	0,0	54,0
C3	100	Exam	E4	8	400	5	0	2	0	8.800	0	3.600	0	22,0	0,0	9,0	0,0	31,0
PL	30	Lab	L1	27	2.700	21	0	0	27	42.000	0	0	216.000	15,6	0,0	0,0	80,0	95,6
PL	28	Exam	L2	1	100	0	1	1	0	0	1.000	1.000	0	0,0	10,0	10,0	0,0	20,0
PL	42	Exam	L3	2	200	2	2	2	1	4.000	2.000	2.000	6.000	20,0	10,0	10,0	30,0	70,0
T	50	Assig	T1	1	100	1	0	0	1	3.000	0	0	3.000	30,0	0,0	0,0	30,0	60,0
T	50	Assig	T2	1	100	1	1	1	1	3.000	2.000	2.000	3.000	30,0	20,0	20,0	30,0	100,0
					#Positive CC evaluations	45	19	19	30	106.400	32.600	24.600	228.000					
					Efectiveness	58,4	38,0	38,0	93,8									

» Graphic results