

Article

Continuous Project-Based Learning in Fluid Mechanics and Hydraulic Engineering Subjects for Different Degrees

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Abstract: Subjects related to fluid mechanics for hydraulic engineers ought to be delivered in interesting and active modes. New methods should be introduced to improve the learning students' abilities in the different courses of the Bachelor's and Master's degree. Related to active learning methods, a continuous project-based learning experience is described in this research. This manuscript shows the developed learning methodology, which was included on different levels at Universitat Politècnica de València. The main research goal is to show the active learning methods used to evaluate both skills competences (e.g., "Design and Project") and specific competences of the students. The research shows a particular developed innovation teaching project, which was developed by lecturers and professors of the Hydraulic Engineering Department, since 2016. This project proposed coordination in different subjects that were taught in different courses of the Bachelor's and Master's degrees, in which 2200 students participated. This coordination improved the acquisition of the learning results, as well as the new teaching methods increased the student's satisfaction index.

Keywords: outcomes competences; hydraulic engineering; hydraulic teaching; active methodology

1. Evolution of Teaching in the University

1.1. New Paradigms in Hydraulic Engineering Teaching

Hydraulics disciplines are in a higher number of degrees related to engineering topics [1]. Civil and environmental engineering courses are an example, although they are not exclusive. There are different Bachelors' and Masters' degrees, in which the fluid mechanics and hydraulic topics are present inside of the students' curricula, such as the mandatory or optative subject.

Teaching involves many methods to reach the learning results. Some of them are: master courses (i.e., a theoretical lesson taught by a professor); design projects; practical activities in the hydraulic lab; and informatic sessions, among others. All actions must provide students an integral and continuous vision of the hydraulic engineering (from fluid mechanics to environmental problems). However, the new students must experiment a necessary change in the new learning methodologies, allowing the students to reach the professional competences satisfactorily. Currently, the European Higher Education plans to decrease the credits to teach, increasing the required skills acquisition by activities, which are not an on-site class [2,3].

1.2. The Significance of the Learning Abilities

One of the problems that students must face is the complexity of numerous concepts in hydraulics subjects (e.g., fluid mechanics). The lecturer usually teaches theoretical matters and the student has to

reach the learning results (e.g., master course, lectures, and exercises) using the professors' information (e.g., bibliography and exercises). Therefore, students must learn materials on their own with minimum guidance by professors. This methodology had good results in the last decades [4]. However, newer student generation demands the development of new teaching methods that rely on new tools. The use of active learning methods is highly recommendable since the students participate in the learning process actively [5]. These methods are based on student activities (e.g., 'playing and learning' using simulations, project-based learning, and role activities) they are a possible solution to improve the students' learning. Continuous project-based learning was proposed across different levels in 2016 as a part of these active strategies [6,7]. The current research shows the results, which were obtained by the coordination between bachelor and master matters from 2016 to 2018.

Currently, numerous researches show the professors should introduce the new learning tools and activities (e.g., simulations, experimental cases, and playing learning) using information and communication technology [8]. Using these tools engages students actively in the learning process. In this line, the Universitat Politècnica de Valencia (UPV) carries out the 'UPV generic students' outcomes 2015–2020' [9]. The main goal of this project is the introduction of 13 generic outcomes, which will improve the students' skills and their curricula [9].

To adapt the new strategic plans, an innovation and educational improvement project has been implemented between different professors of the Hydraulic and Environmental Engineering Department of the UPV since 2016. The main objective is to establish a transversal and vertical coordination in different subjects. The purpose is the acquisition improvement of the learning results by the students. Therefore, the project proposes an evaluation methodology using different rubrics according to the domain level (depending on the year and degree). Besides, the research compares the different subjects in different courses.

In this particular case, this proposal allowed students to start a hydraulic project draft in fluid mechanics topics (e.g., students sized a water branched network). Furthermore, they continued its development in hydraulic machinery matters (e.g., students designed a pump system) and finally, they designed a total project in their last matter fluid facilities (e.g., students sized fluid facilities in a hotel). The development of hydraulic projects, as a learning strategy, is a methodology that was proposed in other universities some years ago. When this method is used, the students must plan, implement, and evaluate complete works, which are applied in real case studies [8,10].

Project-based learning (PBL) allows students to acquire key knowledge and skills through the development of projects that respond to real-life problems [11]. The objective is to enhance students' autonomy. They become the main actor of their own learning process. This training evolves introducing new complex tasks each course using the same project [8]. In this learning process, professors guide and support the students throughout the entire project.

1.3. Hydraulic Engineering Learning Challenges

The stage of the studies of hydraulic engineering must be in constant evolution since the future professionals must face great challenges. These are aligned on terms of sustainability and optimization of the management. Therefore, hydraulics subjects at the university level cover many fields such as: urban hydraulics, watershed management, the pollutants dispersion, hydraulic machinery, river dynamics and restoration, water resources management, hydraulic works, aspects of flows to sheet free of charge involved in sanitation, the water-energy nexus and many other subjects that are being taught in different faculties masterfully. In all cases, the hydraulic engineering is present in the core subject, such as fluids mechanic and/or hydraulic machinery in the engineering bachelor's degree (e.g., electrical, mechanical, and chemistry).

Currently, the knowledge transfer requires the future students must be autonomous and capable. They have to develop skills, which allow them to solve the new challenges. The present manuscript shows the continuous project-based learning experience, which has been developing at UPV. This practice is focused on hydraulics subjects, which are teaching both the bachelors' and

masters’ degree. The proposed teaching project increases the development of real projects, decreasing the hours of lessons. This time decrease is complemented with online material (e.g., teaching video and laboratory tutorials) including workshops and specific conferences. These sessions are developed by companies or guest speakers in the university focused on students.

This research is a good example for engineering bachelors’ and masters’ degrees related to hydraulic and environmental topics at different levels. The manuscript summarizes teaching methodology and results, which developed a teaching project. The experience was carried out at Universitat Politècnica de València. Two thousand and two hundred students participated in thirteen hydraulic subjects, which were part of the teaching project and they were from different years. The students worked the hydraulic concepts using a methodology, in which they reached the learning results through the development of hydraulic projects. The strategy enabled to evaluate both specific and outcomes competences. Before this teaching project, the students were not evaluated of their skill competences and they did not use active methods. Previous to this project, the students’ training was based on master courses and laboratory practices. The participation was up to 80% and the student’s satisfaction was measured by surveys.

2. Materials and Methods

2.1. Structure of the Hydraulic Engineering for a Student of a Bachelor’s and Master’s Degree in the UPV

When the structure of the hydraulic engineering was analyzed at the UPV, there was a complete interweaving with other matters in their different bachelor’s and master’s degrees. These subjects (Figure 1), which were distributed throughout student training, were: (i) basis subjects in hydraulics and fluid mechanics; (ii) subjects related to hydraulic machines; (iii) subjects related to hydroelectric plants and wind power machinery; (iv) subjects related to hydraulic facilities; (v) materials in oleo hydraulic and pneumatic systems; (vi) matters in relation to the water-energy binomial; (vii) matters in computational fluid dynamics (CFD) modeling; (viii) matters in relation to the hydraulic aspects of wastewater treatment; and (ix) matters in relation to the dispersion of contaminants in receiving fluid media.

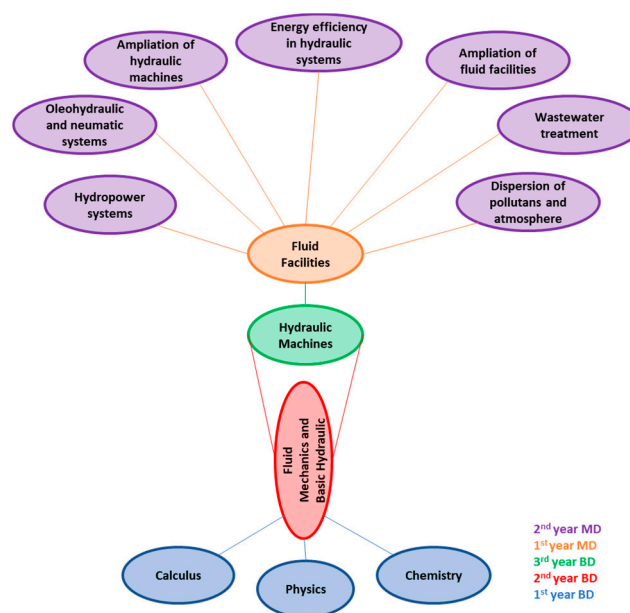


Figure 1. Structure hydraulic engineering subjects at Universitat Politècnica de Valencia (UPV; BD.—Bachelor’s degree and MD.—Master’s degree).

2.2. Learning Proposal Based on Learning Projects at Different Levels, Developing the Transversal Competence “Desing and Project”

The project-based learning (PBL) is a methodology focused on learning, research, and reflection. In this methodology, the students should reach the correct solution of a problem, using an autonomous and continuous learning. This problem was proposed by the lecturer once he/she teaches the theoretical concepts [12]. This methodology was included on the teaching project in the hydraulic and environmental engineering department [13]. It was applied on different matters, which were part of different courses and levels (i.e., Bachelor’s and Master’s). Therefore, the teaching project got a continuous project-based learning (CPBL) in the students’ training [14]. Besides, the CPBL application at different training times of the student enables one to work and evaluate different transversal competences (e.g., time planning, permanent self-learning, and oral communication as well as design and project (DP)).

Time planning was proposed for each subject and it must be followed by both students and professors through the different phases. These steps (Figure 2) were divided on face-to-face and non-face-to-face lessons. The first phase allows students to know the theoretical concepts throughout the master course, the development of computer practices as well as the development of basic problems related to the taught issue. Once these are known, the learning results of each unit should be practiced in progressive development of the project. This practice is non-face-to-face and the students must use information from the UPV webpage. In this section, they have supplementary material. Along this phase, the students work on self-learning and the professor gives them help in group meetings. The collaboration between the professor and students improves the acquisition of the learning results.

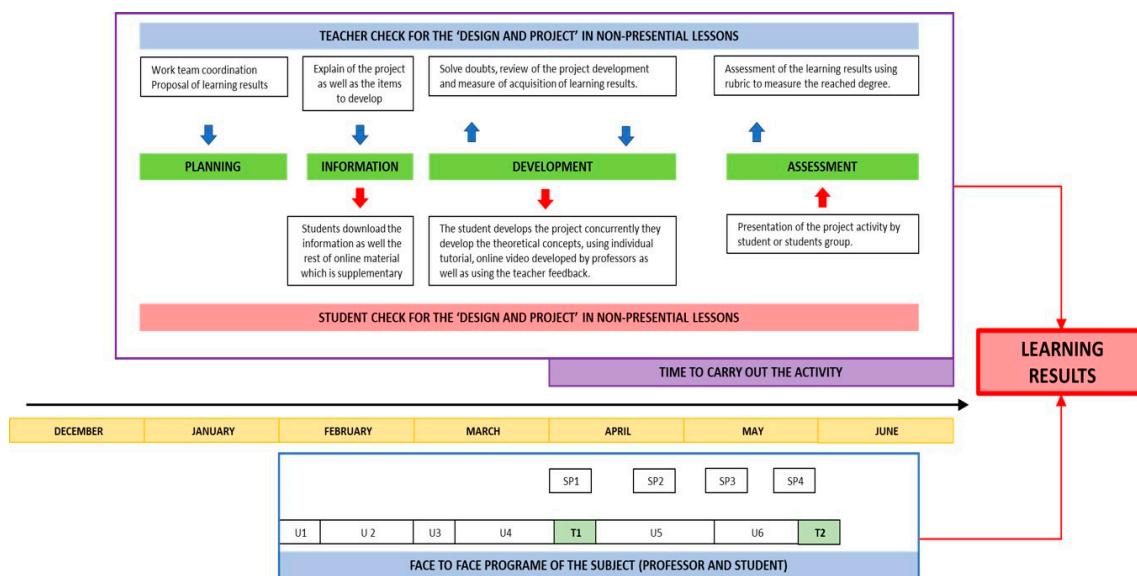


Figure 2. Example of temporal distribution to reach the learning results in a subject (U is unit, T is a test, and SP is simulation practice).

The different activities, their planning, and their dedication were defined using good practices sheets. This sheet was developed by lecturers, and it enabled to coordinate the subject between students and professors, and coordination improved when different teachers participated in teaching the subject.

2.3. Proposal of Rubrics

One of the objectives to develop an active learning is the definition of evaluation items. In this particular case, different rubrics were introduced to combine the evaluation of the student’s competences (i.e., skills and concepts). These rubrics were composed of different indicators, which had

four different descriptors for each one. The indicators measured the acquisition degree of the learning results. Table 1 shows the proposed indicators, which were used to do the proposed rubric (Appendix A). This rubric was used to evaluate the project in hydraulic machines. Other rubrics were published for different subjects: the wastewater network project [6], fluid mechanics [7], or fluid facilities in the chemistry industry [15]. The used rubrics were different in Master’s and Bachelor’s degrees, considering the reached level in the descriptor. In the Bachelor’s degree, the pupils had to design a project with a level of draft. In contrast, the indicators were higher in the Master’s degree, as the developed project should be more specific, and students must be more autonomous.

Table 1. Definition of weighted in the different indicators.

Indicator	Students’ Actions	Weighted
I1.—The student bases the context and the need of the project	Define the need to develop the project	5%
I2.—The student formulates the objectives of the project coherently with regard to the needs detected in the context	Localize them and relate them with the taught concepts. Correct interpretation of the goals allows students to interpret the specific indicators of the follow group (iii) correctly	7.5%
I3.—The student plans the action to be developed effectively	The student has to propose and apply the solved methodology	20%
I4.—The student plans the actions efficiently	Design the proposed system. This group contains seven specific indicators	50%
I5.—The student identifies the risks and inconvenient of the project	Consider the negative and positive aspect of the project related to environmental and social concepts. This indicator is measured using two specific criteria.	7.5%
I6.—Review the results	Review, analyze, and critique with the obtained results, searching incoherent results.	10%

The attached rubric in Appendix A shows the new proposed rubric for hydraulic machines in which specific and skills competences were evaluated. The symbiosis between specific and transversal competences was developed using a matrix, which contained weights and ponderations. The first discrimination was done between ‘not done’ and ‘developed task but the minimum is not reached’. When the student did not develop the descriptor, the numeric value was zero. If the student did the task, but it was not reached, the considered value was 3. If the descriptor was C, the numeric value was 5. When the descriptor was B, the considered value was 7 while the value was 10 when the descriptor was A. Each indicator had a specific weighted value, which was justified in Table 1.

Therefore, the numeric mark (NM) of the specific competence was obtained using Equation (1):

$$NM = 0.05I_1 + 0.075I_2 + 0.20I_3 + 0.50\frac{\left(\sum_{I=1}^{I=7} I_4\right)}{7} + 0.075I_5 + 0.10I_6 \tag{1}$$

This expression enabled one to get the numeric value through descriptors. If the NM was less than 4.5, the learning result was “No reach—D” for transversal competence. When the value was between 4.5 and 6, the learning result was “In Development—C”. A learning result of “Good—B” was reaching, when the NM was between 6 and 8. Finally, ‘Excellent—A’ was reached when the NM was greater than 8.

3. Results

3.1. Students, Subjects, and Proposal of Projects

The project was developed between 2016 and 2019, although it continues currently. In these years, thirteen subjects were taught in Bachelor's (second, third, and fourth year) and Master's (industrial engineering and hydraulic and environmental engineering) degree at UPV. One thousand and one hundred students participated and 13 professors from the hydraulic and environmental engineering department collaborated in the project each year. The manuscript shows results for all subjects although main subjects of the students' curricula (i.e., fluid mechanics, hydraulic machines and fluid facilities) were described deeply in this research. Fluid mechanics was taught in a second-year course of the Bachelor's Degree. This subject was in chemical, electrical, and mechanical engineering degrees (in this particular case, the results were related to the mechanic engineering degree). The students were between 19 and 25 years. One hundred and seventy students were involved, who were divided into two groups for theoretical teaching and four groups for practical classes.

Hydraulic machines was taught in the third-year course of the mechanical engineering degree. The subject was focused on analyzing the pumps-operation principles (velocities triangle and Euler's equation) as well as the machines selection and their regulation according to demand. The students were between 20 and 26 years. One hundred and forty students were involved. These pupils were divided into two theory groups and four practical groups.

Fluid facilities was taught in the first-year course of the industrial engineering Master's degree, after students achieved their Bachelor's degree. The subject contained the analysis of the different types of the fluid facilities, that is, water distribution networks, gas networks, and waste-water networks as well as the facilities, which involved the comfort in society (ventilation and hot sanitary water). For each facility type, the normative, design, analysis, and regulation were analyzed, applying it to the real cases study. The students were between 23 and 30 years. Three hundred and fifty students were involved. These students were divided into seven theory groups and twenty-one groups in practical lessons.

In relation to the fluid mechanics subject, an elemental water supply network was proposed, in which students proposed different diameters for pipes, considering flow and pressure conditions. Once the system was sized, the students had to analyze it using Epanet software [16], considering the constrain conditions (e.g., demand, level node, minimum pressure, and maximum velocity). The sizing was developed as a function on demand over time, using the uniform hydraulic slope criterion. The students run an extended period simulation, analyzing the pressure and flow variations in the different lines. Finally, the students proposed a short budget, considering both length and the chosen material. In this case, the project was supervised by the lecturer. The initial information, which was available for students was: network topology, reservoir head, water demand in each point over time, modulation curve for the different consumption patterns, and the minimum operational conditions of the network as well as the material type and cost of the pipelines. The work was focused on establishing a methodology to develop hydraulic calculus, encompassing the Bernoulli's and continuity equations. The students compared the different studied scenarios as a function of demand pattern using Epanet software.

The evaluation was a formative type. The students did meetings with the professor and they show partial results. The professor verified the calculus and solutions, proposing improvements to students. There were two meetings. The first meeting included the proposal of the network. The second meeting addressed the sizing of the water system. The correction of the project was developed using rubric (Appendix A), and a third meeting was done to explain to students the errors in the project.

The proposed work in hydraulic machines was individual. The activity was focused on analyzing the energy consumption and regulation of a pumped system. This water network was supplied considering two options. Option A: the water network was supplied from a reservoir, which was filled using a pump station and Option B: the water was directly supplied using pump systems. Option A

enabled one to analyze the influence of the reservoir volume in the pump selection (mainly pumped flow) when the energy cost was considered (i.e., schedule and operation time). Option B was focused on applying the similarity laws, regulating the operation curve. The students had to define the rotational speed of the machine as a function of the demanded flow over time. The students defined: the control rules, the operation costs, and the efficiency parameters for each pump system, trying to minimize the cost per cubic meter. The student only had two constrains: demand over time and energy cost, which was the current Spanish energy price.

Finally, when the student undertook the fluid facilities subject, the proposed work had a higher level than previous tasks developed in the Bachelor's degree. At this time, the students were more mature and the cases were near real buildings. Therefore, their training should be more intensive and closer to reality. In 2017, the proposed activity was to develop a complete project (summarize, calculus supplements, drawings and budget, defining the qualities, and normative for the different used materials). The project was related to a complex building (e.g., hotel, hospital, and school since for each students' group it is different). In this project, the students had to connect basic knowledge of fluid mechanics and hydraulic machinery with the new learning results, which are reached in the fluid facilities subject. The students designed the different pipelines and equipment, which were necessary to supply the building (e.g., cold and sanitary hot water system, pumps, and ventilation, among others). This work was developed by teams, composed of three or four students. Once the work was finished, the students had to explain it in an oral session.

In all cases, the students' doubts were attended by teachers. Generally, the questions were solved by face-to-face meetings. However, the doubts solution was also solved using mail and/or a video conference. Throughout the process, the student contacted the professor to validate the different items of the project in each one of the phases and stages.

3.2. Analysis of Results

3.2.1. Results

Figure 3a shows marks distribution in a students' group for hydraulic machines. Each indicator value can be observed for each student. The project mark was the upper 8/10 for 24 students while there were only six students who qualified below 5/10. Each indicator (from I1 to I6) is described in Table 2 and they are drawn in the Figure 3a.

Figure 3a shows the students worked really well I3 and I4 indicators. These were focused on the development of the simulations and the establishment of the control rules in the pumped systems to guarantee the hydraulic constrains (i.e., flow and pressure). In contrast, I5 was the worst developed indicator and it focused on the analysis and discussion of the results. However, the results were highly satisfactory.

Figure 3b,c shows the transposition from the mark to transversal competence in the different subjects that participated in the teaching project (Table 2). If observing the topic hydraulic machines (12659), 77% of students reached the A and B descriptors when the "Design and Project" competence was evaluated. Similar results were obtained in the rest of subjects shown in Figure 3b.

If all subjects were observed the satisfaction was higher, considering all students who participated in the teaching project. The participation in the project development was 82%, considering there were 1051 students in thirteen different matters in 2018 (1149 students were in 2017). When the "Design and project" competence was evaluated, 361 students reached an excellent degree (A). The B degree was reached by 286 students while 154 and 58 (6.75%) students obtained a C and D degree, respectively (Figure 3b).

Figure 4 shows there is a lineal relationship between exam and project marks in two years (i.e., 2016/2017 and 2017/2018). Therefore, the development of the activity helped students to acquire the hydraulic concepts as well as the methodology. Although there were no exams when PBL was applied, in order to compare the previous (traditional method using master courses) and new methodology

(CPBL), an exam was proposed. This improvement contributed to reaching the learning results favorably. This trend was observed in majority of the studied subjects. Besides, when the project delivery was after the exam, the test mark did not have a relationship between them. Therefore, there was a greater significance to establish the date delivery before the test. The final marks were compared with previous years. The score increased around the 1–2 point about 10, reducing the number of students who failed the subject (6% in 2016/2017 and 8% in 2017/2018).

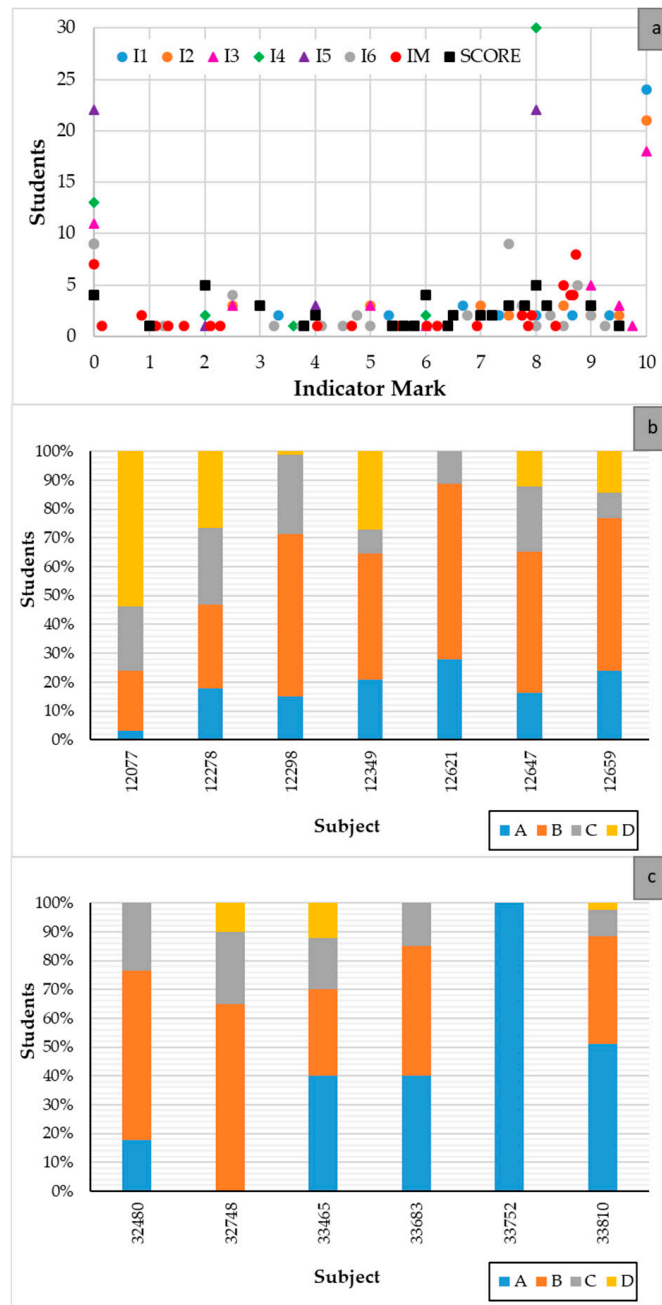


Figure 3. (a) Indicator in hydraulic machines related to Table 2; (b) results of the descriptors in the “Design and Project” competence for the subjects of the Bachelor’s degree defined in Table 3; and (c) results of the descriptors in the “Design and Project” competence for the subjects of the Master’s degree defined in Table 3.

Figure 4 shows the correlation between project and exam marks was strongly correlated when the students did not do the project correctly or they got a mark up to six. However, when the students

developed an excellent project (mark between 7 and 9), they did not always get an excellent mark in their exams. It could be due to the student's collaboration and working on other skills such as analysis and resolution of problems. When they did the exam, the help between partners was not there, and therefore, they had to solve their doubts, which in some cases were not resolved correctly.

Table 2. Subjects of the teaching project.

Code	Subject	Bachelor's Degree	Master's Degree
12298	Hydraulic machines	Chemical Engineering	-
12621	Fluid Facilities in Building	Mechanical Engineering	-
12621	Fluid Mechanics	Chemical Engineering	-
12077	Fluid Mechanics	Electrical Engineering	-
12647	Fluid Mechanics	Mechanical Engineering	-
12349	Fluid Mechanics	Chemistry Engineering	-
12659	Hydraulic machines	Mechanical Engineering	-
33810	Fluid Facilities	-	Industrial Engineering
33752	Waste water treatment	-	Industrial Engineering
33465	Fluid Facilities in the chemical industry	-	Chemical Engineering
32478	Waste water networks	-	Hydraulic and Environmental Engineering
33683	Extension of Fluid Facilities	-	Industrial Engineering
32480	Analysis and modeling of water networks	-	Hydraulic and Environmental Engineering

Table 3. Questions related to planning.

ID	Question
Q1	Does the proposed activity allow you to apply the knowledge developed in theory classroom and practice lessons?
Q2	Does the temporary planning to develop the project design throughout the course allow you to start the activity well enough in advance to developing it properly?
Q3	Is the index developed by the teacher explaining the methodology and phases of the work, sufficiently clear and concise, to develop the proposed activity?
Q4	Did the project help you to acquire the knowledge, and to prepare other evaluations (e.g., tests and problems) of the subject?
Q5	Would you find it interesting that the development of the project proposed in this subject involved other subjects of your grade?

3.2.2. Surveys

Two different surveys were developed for each subject. First survey gave information related to the subject planning. This survey helped to analyze if the coordination between taught concepts and project development was correct. Related to this, five questions were proposed (Table 3). These questions were related to: (i) the application of the activity with the concepts, which were taught in the classroom (Q1); (ii) the synchronism between activity and taught concepts (Q2); (iii) if the index developed by the professor to explain the methodology was clear (Q3); (iv) if the project development helps student

to reach the learning results and train to do the evaluations (Q4); and (v) if the student would be interested in development of a project considering different subjects of the degree (Q5).

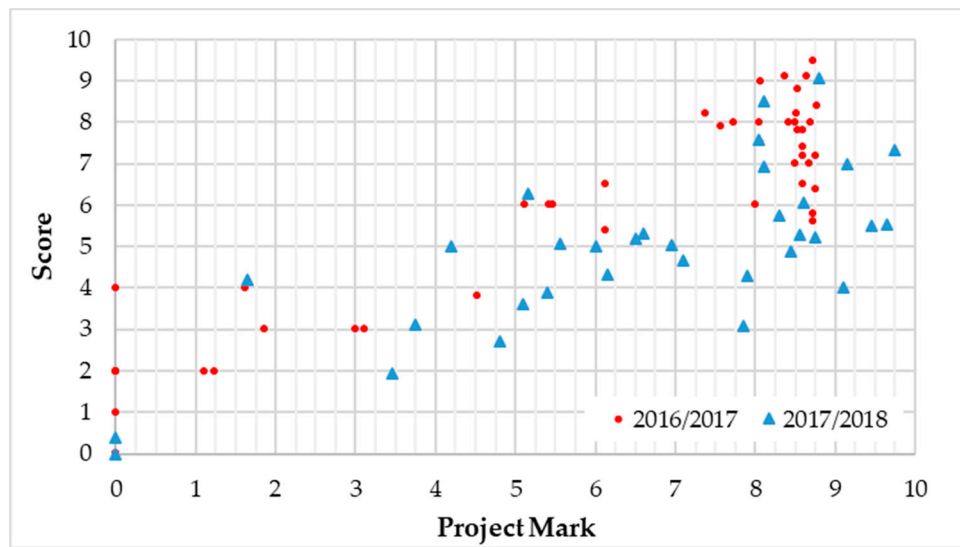


Figure 4. Relationship between the exam and project marks in hydraulic machines.

Figure 5 shows the results in the survey when it was done in hydraulic machines. The figure shows the results once 103 students (76%) answered it. There were 90% of students that positively agreed with Q1. This percentage was higher compared with other subjects in the UPV. This was a goal of the project, since it wanted to develop activities to increase the satisfaction in the students. These activities were focused on: (i) increasing the simulation lessons with software, (ii) visiting some buildings where the students can identify the studied facilities, and (iii) increasing the number of online videos in which they can visualize real solved case studies. In both years, the answer was similar between students. Therefore, they considered positive the use of this methodology to apply the teaching concepts.

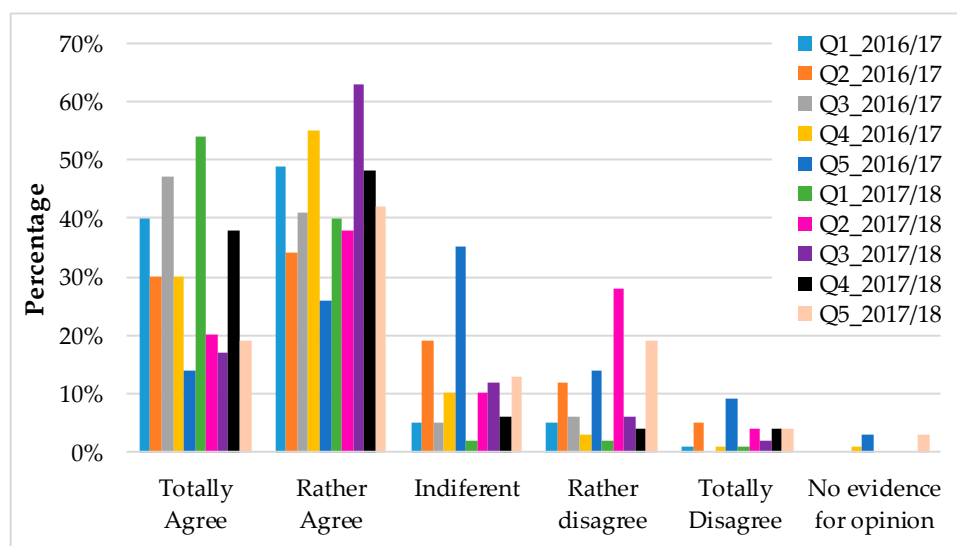


Figure 5. Survey to analyze the development of the project in the topic: hydraulic machines for the 2017 and 2018 years.

The rest of the questions were mostly approved. They showed the majority of students agreed to develop the teaching methodology. Similar results were obtained in fluid facilities (Figure 6).

The surveys analysis showed the student accepted this methodology although they had to invest more effort in the subject continuously. This learning obligated students to develop a planning to reach the objectives. In this case, results from only one year were presented, since the Master’s students only undertook a course in the active methodology in 2017 (previously, they undertook a course in for their Bachelor’s degree on the topic hydraulic machines using this teaching project).

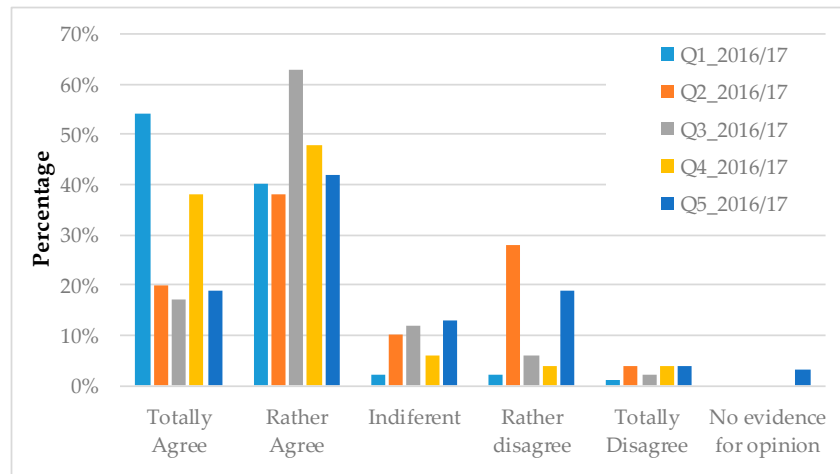


Figure 6. Survey to analyze the development of the project in fluid facilities.

Figure 7 shows the results of a survey, which had four questions. The survey was proposed to students in the second-year or third-year level (once the student studied fluid mechanics). The questions measured the vertical coordination between subjects. The questions (Table 4) were related to: (i) the developed project that helped students to improve the acquisition of competences (Q6); (ii) if the development of the project, which was developed on fluid mechanics in the previous year, helped to improve the development of the project in hydraulic machines (Q7); if the previous study of the hydraulic concepts helped students to develop the project (Q8); if the use of a similar methodology between the project developed both fluid mechanics and hydraulic machines that helped students to develop the project in the hydraulic machines topic (Q9).

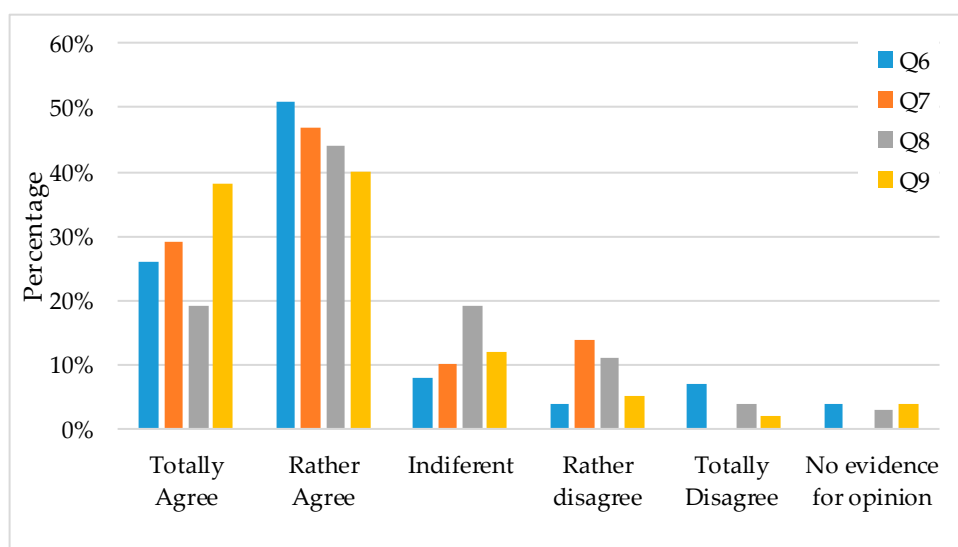


Figure 7. Survey to analyze the vertical coordination between subjects that are located on different courses and levels (Bachelor’s or Master’s degree).

Table 4. Questions related to coordination between years.

ID	Question
Q6	Does the development of a project that is related with studied subjects help you to improve the knowledge acquisition and competences in the 'design and project'?
Q7	Does the development of the project in fluid mechanics help you to understand and develop better the practical applications in hydraulic machines?
Q8	Does the study and understanding of common hydraulic concepts in different subjects help you to do the project?
Q9	Does the use of a similar methodology, which was used in fluid mechanics to do the project, give you autonomy to do the project in hydraulic machines?

If Figure 7 was analyzed, it shows that the majority of students (upper 60%) considered the application of this methodology positively and it had influence on achieving good results in the development to their competences.

The developed experience verified that the students improved the acquisition of the learning results in the different subjects when they were compared with the previous years. Therefore, the professors' experience joined to the students' opinion show the development of active methodologies increased the positive attitude of the students. This emotional state made the students show a greater interest in the subject, improving their efficiency. However, this effect cannot occur in some cases, in which students think they learn a lot in these scenarios, but when tested they really are not. This occurs when the students do not work in the activities continuously and correctly throughout the year.

Similar strategies are being developed currently in UPV and other universities to motivate students to develop continuous learning. Currently, the development of projects is being planned at an institutional level. The learning project includes subjects that are part of different years and are in different areas. This situation improves the integration of the subjects in the students' curricula. Besides, the students understand better the significance of the different subjects when there is a global learning project. It occurs even though the matters are studied in different years. The project existence allows students not to view the subjects individually, interrelating the different matters.

This methodology can be extrapolated to other knowledge areas or degrees, adapting the projects to the learning results of each subject. The success of this methodology is verified in other countries and universities [2,3,17]. The development of the good practices sheet [16] and the definition of the learning goals allow one to organize the active methodology for any subject.

4. Conclusions

A case study was described in this research, which joined different hydraulic engineering topics. The subjects were taught using continuous project-based learning. The implementation of this methodology was new at UPV to develop the skills competences in the students. The development of the methodology from basic subjects (i.e., fluid mechanics) enabled one to define the procedure, which can be applied on subjects at the upper level. The methodology allowed professors to establish a schedule in which face-to-face time and a non-face-to-face lesson fit perfectly. Therefore, the use of a good practice sheet allowed students and professors to know their activities for each time. The use of these sheets improved the synchronization of the teaching (i.e., theoretical concepts, practices lessons, and activities) between them. Besides, the development of the good practice sheet helped professors to organize subject learning. The good practice sheet contained different tasks, which should be carried out by professors and students, defining the data and time of their development.

The proposed methodology is crucial to give students an action strategy when they have to develop similar projects in matters of the hydraulic area. The strategy improves the vertical coordination in the Bachelor's or Master's degree. This organization maximized the reach of the learning results since it

mixed a face-to-face class and online videos and material as well as real projects to apply the taught concepts according to the students’ capacity.

The methodology included a rubric for each subject. These evaluation criteria enabled us to evaluate the acquisition of the learning results, joining both specific and transversal competence of the ‘design and project’. The rubric, which was used in hydraulic machines was shown in this manuscript (Appendix A). It defined the specific indicators and the descriptors, which are necessary to develop the project. Besides, the used expression, which correlated the specific and transversal competences in the students’ curricula, was presented.

Two surveys were proposed to students. These questions showed the students’ satisfaction for the structure of the activity. Besides, they considered it necessary to improve the acquisition of the learning results. The students were grateful of the use of this methodology in other subjects related to hydraulic engineering topics.

Finally, the new challenge in teaching should be focused on:

- Professors need to establish active methodologies in which the students are involved, improving their learning results.
- The students’ training should be coordinated in order to align the specific competences and outcomes competences as well as the sustainable development goals.
- Communication technologies (ICTs) joined to use software are tools, which must be incorporated in the teaching guides to improve the learning results and, therefore, the students’ curricula.

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Appendix A

Table A1. Specific indicators used to evaluate hydraulic machines.

Indicators (What Is the Analyzed Point?)	Descriptors			
	D. Not Achieved	C. In Development	B. Good	A. Excellent
1. The students bases the context and the need of the project	The student explains the need of the project but he/she does not justify	The student justifies the need of the project, using opinions that are not checked enough	The student justifies the need of the project correctly but it is incomplete	The student justifies the need of the project correctly and completely
Introduction and justification	There is not a definition of the goals	The student introduces the project to do but he/she doesn’t justify its need or he/she does it incorrectly	The student introduces the projects but he/she does not justify the need	The student introduces the projects and he/she justifies the need
2. The student formulates the objectives of the project coherently with regard to the needs detected in the context	The student formulates the goals without considering the needs	The student formulates the goals but they are not coherent with the needs	The student formulates the goals and they are coherent with the needs	The student formulates the goals and they are coherent with the needs and these goals are operational
Goals	There is not a definition of the objectives	The student establishes the goals but these are ambiguous.	The student defines the objectives sufficiently	The defined goals are clear and operational
3. The student plans the action to be developed effectively	The student does not develop the justification of the action	The students develop the plan partially to reach the goal	The students develop the plan to reach the goal in their major points	The students develop the plan to reach the goal completely

Table A1. Cont.

Indicators (What Is the Analyzed Point?)	Descriptors			
	D. Not Achieved	C. In Development	B. Good	A. Excellent
For each section of the project	There is not a plan	The student does a short description or justification	The student describes and justifies the development only considering an academic point of view	The student describes and justifies the development, considering both the academic and technical point of view
4. The student plans the actions efficiently	He/she does not plan efficient actions	He/she plans efficient actions, although they are improvable	All actions are not efficient	He/she plans efficient actions completely
Setpoint curve	It is not calculated	It is calculated incorrectly	The result is correct but there is no discussion about this	The result is correct and there is an analysis of the result
Reservoir capacity	It is not calculated	It is calculated incorrectly	The result is correct but there is no discussion about this	The volume is correct and there is an analysis of the result
Pump selection	It is not developed	It is developed incorrectly	The result is correct but there is no discussion about this	The selection is correct and the student proposes alternatives (other types and manufacturers)
Pump selection when the network is pumped directly. Considering non-variable rotational speed	The new selection is not developed according to the setpoint curve	It is developed but it is incorrect	The developed selection is correct but it is not justified	The selection is correct. Besides, the student develops a justification and comparison, considering other solutions
Economic analysis when the rotational speed is fixed	The student does not develop the daily analysis	The student does the analysis but it is incorrect	The student develops an analysis correctly but the analysis is not justified	The student does a detailed analysis, developing indicators and comparing with others facilities
Pump selection considering variable rotational speed	The pump selection is not developed according to the new setpoint curve	It is developed incorrectly	The developed selection is correct but it is not justified	The selection is correct. Besides, the student develops a justification and comparison, considering other solutions
Economic analysis when the rotational speed is variable	The student does not develop the daily analysis	The student does the analysis but it is incorrect	The student develops an analysis correctly but the analysis is not justified	The student does a detailed analysis, developing indicators and comparing the values when the rotational speed is fixed
5. The student identifies the risks and inconvenience of the project	The student enumerates some risks but they are not analyzed	The student enumerates some risks but they are not analyzed deeply	The student enumerates some risks but they are analyzed but he/she defines constraints to solve the problems	The student enumerates risks, they are analyzed and solved for improving the project
Conclusion section	There is no conclusion	There is a conclusion, but the student does not discuss the results	Different results are discussed and compared	Results are compared, establishing the advantages and inconvenience for each solution
Language, format, and writing of the project	The presentation is poor, the writing and language style are not at a high enough level according to their academic status	The presentation is correct although the language is not at a high enough level since the student uses no technical words	Presentation, language, and writing are correct but the content exceeds the limit	Presentation, language, and writing are correct and the project is adjusted to the requirements established by the professors
6. Review the results	The student does not review the results	The student reviews the results but the review is not structured	The student plans the result evaluation (i.e., who, when, and how)	The student plans the result evaluation (i.e., who, when, and how), using indicators
Review the results of the facilities using EPANET	There is no evaluation	All results are not checked	All results are checked without doing comparisons	All results are checked. The student develops comparisons between a classmate or comparing values that are obtained from the bibliography

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