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Competition-based Learning in Engineering Degree Programs*

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Competition-based learning is a technique in which students compete when performing an activity or a series of tasks with the objective of enhancing motivation, communication skills and creativity. This paper presents a literature review to determine whether competition-based learning improves students' engagement and motivation in the context of engineering studies related to the Information Technology. It also investigates parameters that make the approach successful for those studies.

Keywords: competition-based learning; competition; engineering; active learning; gamification; group; motivation; engagement

1. Introduction

It is now a reality that University students must receive theoretical and practical knowledge while they should also acquire other occupational skills [1]. Creativity, self-learning and communication skills are also necessary for their future careers. These competences must be achieved in the current environment where students are overloaded with huge amounts of information. This may cause a diminution of students' motivation.

Consequently, it is necessary to judiciously use learning techniques that make students participate actively in a more stimulating environment so that the learning process will be more engaging and solid. Among these techniques, competition by itself or combined with other learning practices have demonstrated its efficacy to increase students' interest [2]. Competition-based learning (CBL) consists of establishing a single task or a series of activities that must be solved by the participants (i.e. the students) individually or in groups. The results of the students are evaluated and ranked so that some winners are called. The winners can be proclaimed for each task (with tournaments) or at the end of the tasks if there is a league set. The winners can be selected according to several criteria. For instance, one of the criterion could be the time that they required to complete the task [3]. Alternatively, the quality of the presented work could be evaluated to identify the winners [4]. If properly designed, the learning outcome should be related to the student's score. As for motivation, competition-based learning may have an impact on the final evaluation of the student [5].

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Establishing a competition-based learning process could report several benefits to the students. As stated in [6, 7], the students' participation, their learning performance and their creativity are improved when a competition is set in a class. The analysis in [8, 9] also detected that their motivation is enhanced when these circumstances take place. In addition, the competition helps improving the relationship with other groups, which may facilitate the enhancement of the communication skills. However, introducing this active learning technique is complex. First, we have to match the activities to the learning objectives [7]. There are also key issues to define when implementing a competition-based learning approach. First, we have to decide if the students compete individually or in groups. The competition can be established only for a class, for several classes in the same institution or it can even involve groups from different educational centers [10, 11]. As for the stages, the competition can be tailored for only one activity or for a sequence of tasks. How scoring is performed is also relevant for an appropriate learning process.

As can be observed, the implementation of a competition-based learning process is not trivial as its success depends on how the aforementioned issues are configured. Some negative effects may arise in a wrongly-implemented competition based learning [12]. The most relevant drawbacks associated to this technique are: increase of anxiety, frustration [13], damage of interpersonal relationships or favoring only good students while those who perform poorly feel frustration [14, 15]. When there is a group-based competition, one of the most outstanding limitation of these activities is unfair distribution of tasks in the team. The work reported in [3, 16] already addressed the importance of one of

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the configuration parameters of the competition-based learning. In particular, they analyzed the impact of how the groups are selected in the competition. The definition of rules and metrics revealed itself primordial in the research results in [7].

If these potential drawbacks are avoided when tailoring the competition activities and rules, the learning outcomes are increased. In particular, a proper implementation of a competition-based framework can help engineer students to develop the high number of skills that will be required in their career. As defined by UNESCO, an engineer must combine the development, acquisition and application of technical scientific and mathematical knowledge in his career to conceptualize ideas for the design, development, deployment and testing [17]. Recently, more competences are demanded for engineers such as being able to collaborate with peers or being creative and competitive to better place their product in the market [18]. It is observed that not only theoretical concepts are demanded to the Engineers, but they are supposed to acquire practice with the management of industry-grade test equipment and testbeds in the laboratory subjects. Engineering education has evolved to provide all these skills, using innovative and active learning techniques in this process. The Competition-based approaches may be a good practice to reinforce all the skills engineers need.

This study specifically attempts to answer the following research questions:

- Does CBL improve learning outcomes in engineering degree courses?
- What are the main issues that must be considered when implementing a CBL practice?
- Does competition increase engineering students' engagement?

To address these questions, this paper reviews some implementations of the competitive learning process in higher education courses, specifically in engineering degree courses. First, we studied CBL experiences in subjects that develop skills related to Information Technology (IT), like computer science or telecommunication systems. Moreover, other approaches that benefit from IT like smart industry, electrical circuits and efficient energy management are also covered. This selection is also due to the expertise of the authors, whose teaching experience is closely related to those types of subjects. Moreover, a special attention will be paid to gamification in the studied literature because of the important results that those works obtain about improving students' motivation.

The search process has been driven over the following databases:

- Google Scholar.
- IEEExplore.
- ScienceDirect.

The keywords used to find out those papers can be split into two categories: general learning methodologies and engineering programs. So, the main keywords to select CBL related papers were: competition, competitive learning, gamification and engagement. Thus, to find papers under the specific engineering area the keywords used were: higher education, engineering, computer science, telecommunication, programming languages, electrical engineering and chemical engineering.

From the set of papers found under those search keywords the selection rule was based on the following criteria:

- CBL experience in the European Union (EU) because of the similar higher education model.
- Novelty of the approach. Papers from the past five years were chosen preferably while papers published before 2015 can be taking into consideration.
- Papers that report about actual experiments with students in engineering degree programs.
- Papers that reference the work. At least it was required one or two referencing papers per year after publication. For papers with ages over ten years it was required an important amount of references (100 or more) that justify their importance to be commented.

With these requirements, the typical selected paper is one that covers an experiment with CBL in an engineering degree program in a country of the EU in the past five years that was referenced by approximately 10 papers.

2. CBL in Some Areas of Engineering Degree Curriculum

This section describes several published research results on competition-based leaning (CBL) in the area of engineering degree programs. Specifically, we have first focused on CBL related to Information Technology because of the teaching experience of the authors. Then, we have extended it to electrical and chemical engineering, which are related to the research activities of the authors. Therefore, the present review is based on engineering degree programs that are close to several current trends in engineering like the development of Internet services, computer networks, smart industry or efficient energy management. It must be also stated that engineering degree curricula include a broad set of subjects, which can be grouped into areas. The theoretical and practical skills that the students

must develop in each area differ and, consequently, the application of competition as a learning technique may be different for each one. Next, we review how the competition-based learning has been applied for some of the previously mentioned areas in Engineering.

2.1 Computer Programming and Software Management

Computer programming skills has traditionally been developed and improved by practice. Thus, students are oriented to implement their own computer programs to solve exercises or examples proposed by their lecturers. Therefore, competitive learning based on software development tasks has been employed in a wide variety of experiences and examples in higher education. One of the most common and well known method is the programming contest. In this type of competition, students try to beat other participants in an open or limited programming contest, usually held by other educational or technological organization apart from theirs like the ACM International Collegiate Programming Contest (ACM ICPC) [19] or the International Olympiad in Informatics (IOI). In these competitions, students, led by the teacher or lecturer, usually work forming teams during a semester or a whole year to present a program of any other kind of software implementation that have to solve a complex problem or to offer a new and innovative solution. Consequently, students that participate in this contest collaborate with their university classmates to beat other teams from different course groups, degrees or universities.

Competitive learning based on programming contest are often based on online platforms or online judges like UVA On-line Judge [20]. In this tool, students are automatically evaluated to fulfill a score-based competition with their classmates or even considering competitors from other universities. In this contribution, Revilla et al. emphasizes the goodness of this type of methods to catch students' curiosity and motivation through nonacademic problems. UVA On-line has also an evolution chart that tracks the performance of each user to show their achievement of programming skills. However, authors warn about the risks of this kind of learning method, mainly due to the fact that actually only one can win a contest. As a consequence, instructors should be aware about those drawbacks and make their students aware of their own improvement in programming skills during their participation in the contest. Other contribution that shows an online platform to train students in programming skills is the virtual laboratory VPLUM [21]. It is aimed to promote the participation of the students in contest like ACM ICPC while it also motivates and fosters students learning. It is evaluated by programming experts and by students. In [22] the authors conduct an experiment using the online judge Mooshak [23] for a second-year course on programming. In this particular subject, there is a very high rate of dropouts (between 2/3 and 3/4) of the enrolled students. The methodology used in this experiment removes the final exam and offers different activities to the students. One of those activities is the contest-style one and even one based on designing their own problems. The research results show an important dropout decrease, from 72.3% to 44.8% and the 77% of the more than 300 students that were enrolled in the experiment agreed that they had learnt better with this method.

In addition, online judges are also developed including teaching features to make them an effective tool for student evaluation. In [24] it is presented Jutge.org, which can be consulted today. It is organized in courses and has different user profiles (Students, Tutors, Instructors and Administrators). Thus, a student has a place to solve different programming problems that can be tutored or guided by lecturers. Jutge.org is also used as a training platform for other computer programming contest like the above mentioned ACM ICPC. However, this approach is not aimed for pure competition although it is suitable to foster motivation and self-competition because Jutge.org automatically evaluates the solutions submitted by students.

The evolution of this online judges is the interconnection between them in one learning management system (LMS) to cover competition and assessment. Within this category, EduJudge [25], an evolution of UVA On-line, presents an experiment that uses the results obtained in the online judge into the assessment of a subject. EduJudge is composed of three main subsystems: (i) an evaluation server, that gives more detailed results about the solution of a problem, (ii) a learning objects repository and (iii) a user interface that connects the online judge with Moodle. Specifically, EduJudge is embedded within Moodle as a new type of question for any other activity. EduJudge was tested in engineering degree programs not focused on computer science. The students were split up into two groups (the experimental one and the control group). The results were compared with the results in similar subjects the following academic year. The research results, based on an integrated tool of Moodle to organize competitions (QUESTOURnament), show that students of the three different degrees who participated in the experiment achieved significantly better academic outcomes that those that belonged to the control group.

Moreover, the score obtained by students in the EduJudge group is less dispersed than the score for the students in the control group which demonstrates a more homogeneous improvement in programming skills. In addition, EduJudge was evaluated positively by the students, throwing a mean of 3.273 from a maximum of 5.

Other types of contests are those that are based on the common programming tasks of the subject without linking them to programming problems in an external contest. An example of these experiment is the one guided in [26] where students compete, and also collaborate in small groups, in a similar competition to the UEFA Champions League play-offs. The experiment is supported by a custom application that helps to manage the available exercises, the students' submissions and other aspects of the competition like the classification and the scoring. After the experiments, the students were surveyed about the experiment. It was evaluated extremely positive. Moreover, this kind of in-subject competition can be also combined with other methodologies like project based learning. In [27] the students, working in teams, compete to develop their own Android application. In this case, the results for the student perception about their improvement in Android programming skills show an important increase from the perception before the course. Taking into account the evaluated applications, the results score a mean value of 331 points from 10 points (the minimum) to 500 points (the maximum).

Taking into account contests within a subject, other competitive learning approaches focus on other aspects like time to complete the tasks. Thus, in [3] the authors proposed a competition based on the Olympics Games where teams of students compete to finish their programming tasks first. The first team is awarded with a gold medal, the second team with a silver medal and the third with a bronze medal. Each medal won in a task supposed a special reward in term of bonus points for the final marks of the subject. The research results, which involves students from two subjects of the second and third year of Telecommunication Engineering degree course, show that students increased their motivation and the quality and innovation of the finished work improved significantly.

In competitive learning, gamification is currently one important trend that applies for programming competitions [28]. In gamification, the contest is changed by a game to improve student engagement, which is usually the main problem in programming subjects due to the abstract topics they have to face. It is played through the different tasks developed by the students during the course. This kind of experiment usually splits up the assessment of the subject into minor milestones or achievements similar to those that exists in board games or video games. Therefore, when the students finish an evaluation task, like exercises or laboratory practice, it usually means that they score some points in the game or advance in the timeline of the game. An example of successful application of gamification for learning Android programming is the research result detailed in [4], where the authors resemble the assessment tasks of the subject with the jump that a famous hero makes in a platforms video game. Therefore, the highest the student marks are, the highest the hero jumps, so they earn more points and reach new levels with new rewards. Those rewards, or gadgets, are mainly focused on improving their result. However, there are a set of gadgets that can be used to hinder others progression so that the game is more attractive. The experiment was driven over three different courses for third year students of telecommunication engineering degree course. Although the number of students who participated in the experiment was low (around 30), the results show and important improvement in students' engagement and performance.

Another example of gamification is shown in [29], where the authors developed a gamification scenario to support the competition learning in the course Software Project Management. In particular, they set four milestones to develop a Formula-1 simulator. In each milestone, a winner is proclaimed, and the other teams continue the competition with the material developed by the winner. The two teams with the biggest scores were rewarded with the highest exam grade. The participants detected some inconveniences in this approach. First, they had to continue with a code that they had not developed, which added complexity to the remainder of the competition. That code was even with bugs, which made them more difficult to progress. Second, the coordination in a team was a hard task due to the group size.

2.2 Telecommunication Systems

Telecommunication systems are present in a wide variety of engineering applications. This circumstance has prompted that communication theory must be in the theoretical background of all engineering students. This area is constantly evolving with new techniques and the definition of advanced standards. Due to this complexity, active learning techniques are especially suitable for this kind of subject [30].

In [7], students in the third year of their Telecommunication Engineering degree programs design and develop optimized versions of the radio transmitter and receiver with SDR (Software

defined Radio). Specifically, they focus on the physical layer processing the chain of an LTE-like downlink transceiver. The competition is organized in 20-minute matches. In each match, two teams face each other. To beat, the optimized wireless communications system developed by the winner must outperform the other team's system in terms of bit error rate, block error rate, throughput or error vector magnitude. Students are also in charge of evaluating the work delivered by other groups.

The matches are grouped into two challenge formats, Champions League and LaLiga, which are two popular football competition frameworks in Europe and Spain respectively. As in the football Champions League, there is an initial qualification phase in which the teams must demonstrate that they have met a minimum performance in order to participate. The next matches follow a play-off format. Alternatively, the competition referred to as LaLiga sets weekly matches. The teams earn some points if they win or if there is a tie. A general classification board is published to keep track of these activities. The authors detected that students could have a greater engagement but they were disappointed by the load that the competition may have. Frustration may be also due to the method used to define the groups. An important conclusion of this work relies on the fact that the grades of the students were correlated to the classification they obtained in these two competition approaches. This demonstrates that the design of the activities was good enough to achieve the learning objectives.

The work in [9] incorporates competition into a software learning tool to teach Communication Networks. The experience can be configured to compete individually or in pairs. The application described in [31] shows that the students were first split up in pairs and then, the pairs were merged into bigger groups. This approach is intended to reduce the stress of working with unknown peers. The students must solve some challenges in a given interval of time. Challenges are proposed by the students as questions. The students must solve them correctly and quickly as answering fast is very important since the score for solving a challenge decreases once the first correct answer is submitted. A scoreboard shows the progression of the five highest scored students. In addition, the solutions of other participants are made public once the competition is finished to enrich the learning process.

2.3 Smart Industry

The adoption of information and communication technologies in a massive way in the industrial field has given rise to the concept of smart industry or Industry 4.0. The adoption of this new technology implies the development of new capacities and skills in the industrial field. The technologies [32] to be adopted are related to telecommunications, big data, robotics, Internet of Things (IoT), cyber physical systems, security, etc. The acquisition of these new skills can be done from the field of gamification through different initiatives that we comment on below. Some of the initiatives have been tested both at university and as additional training in some companies. There are many proposals for action but few real examples.

One of the first experiences that develop gamification in a subject related to smart industry (Cloud Computing), is described in [33]. The authors present a gamification system based on points and with multiple rewards. In such a way, all the intrinsic motivation types defined in [34] are promoted during the competition: explorers, achiever, socializers and winners. The passing rate was over 75% at the first attempt.

IoT is one of the main foundations of the smart industry and it should be a theoretical background for future engineers. The authors in [35] present a Virtual Learning Environment called IoTCityLab to motivate students in this discipline. A multiplayer project is presented in which tasks have to be carried out to tackle a realistic project as the testing of autonomous vehicles. The gamification of subjects related to IoT not only occurs in the university environment, but there are experiences developed in institutes to promote STEM studies. One of the biggest challenges in the smart industry is energy saving, so the authors in [36] present an experience in which they use a web-based game and an IoT-kit to reduce the energy consumption of the building. They propose gamification activities with a competition phase between teams and developments in the start-up laboratory of different sensors in a secondary school class. Similar strategies are found in [37].

In the field of telecommunications [38], a course related to the digital economy was gamified in such a way that students must make a video and an essay that will be finally evaluated and will get prizes and publication in a blog. Continuing in this field, Cybersecurity topics are presented in [39] through a gamification based learning, in which different methods are mixed to achieve a balance between fun and learning complex concepts. The results express an improvement of the students in different skills, although the study is limited by the small number of participants.

Most experiences in the industrial field are related to the use of machinery and other automated elements. However, there are aspects that still have to be done manually such as assembly and

logistics. The authors in [40] present an experience in which Augmented Reality is used to improve the capabilities of workers on an e-longboard (electrically driven longboards). The experience developed is basically individual and incorporates tasks in which precision and time are measured as fundamental aspects.

The authors of [41] introduce the most important aspects of Industry 4.0 into the university curriculum. To do this, students attend to an orientation program and are subsequently divided into groups. Tasks are assigned to these teams. The tasks consist of designing an intelligent production line and designing the prototyping process. The tasks are divided into several activities so that students become familiar with the most important industrial topics. Finally, an evaluation of the knowledge and the new skills acquired is carried out.

2.4 Electrical Circuits

The vast majorities of engineering degree programs include a course on basic electrical circuits in their curriculum. Electric circuits are composed of a set of electric interconnected elements such as sources, resistors, inductors, capacitors, etc. The main learning objective of this course is to apply basic techniques to analyze such electric circuits. Using competitive learning in this subject is definitely a way to increase student motivation and participation. For instance, 10 years ago, the authors of [42] described the experience and learning benefits of using competitive learning in the subject ''Electric Circuit Theory'' at the University of Valladolid using the MOODLE platform. The proposed competitive learning rules are based on a dice game called Quinito. Basically, students are split into teams and solve problems sequentially. First, students of Team A solve a problem, and students of Team B must decide whether it is incorrect (and provide the right answer) or correct (and solve the following problem). Professors found out that this competitive learning strategy reduced the number of students who fail the subject by 15%. More recently, the authors of [43] discuss their experiences in electrical engineering courses at Birzeit University regarding the implementation of teaching methods where cooperation and competition can coexist. Student were split into groups that were freely decided by the students. The proposed procedure is inspired by sports competition and included a preparation phase (during which the members of the different teams solve different electric circuits and share knowledge) and a final confrontation (during which the members of the different teams must answer test sheets individually). After analyzing the results, the authors concluded that this approach improve students' engagement and cooperation in the learning process.

Unlike the two previous approaches, others incentive the individual competition among students. For instance, reference [44] describes the development of a web application with an extended list of electric circuit exercises whose input data is different for each student. Students get points for each exercise correctly solved in order to improve their position in the class ranking. Professor realized that including the ranking significantly increased the use of the web application by students.

On a different front, game-based competitive learning has also been implemented in virtual worlds as described in [45, 46]. These environments include advanced communication and interactive simulation tools that allow for distance learning activities, for example. In particular, the Circuit Wars project demonstrates how immersive virtual worlds can be used in Electric Circuit subjects at the University of Ulster. Under this virtual framework, students compete individually to solve, for example, electric circuits that they visualize through virtual reality and get points according to the time required to solve them. The authors show how virtual reality can be used to create a game based teaching environment in a competitive format that engage students and enhance the learning experience.

The references above basically address the learning of theoretical aspects of electric circuits. Next, we present some research that discuss competitive learning using concrete applications of electrical and electronic engineering. For instance, reference [47] describes the competitive approach implemented in an undergraduate class in mechatronics at Santa Clara University. As in previous approaches, students are split in 15 teams that must design a robot using Arduino technology to successfully complete a given task. Each team obtains points according to the abilities of the robot to comply with the desired tasks. Similarly, the authors of [48] describe a competition-guided teaching strategy used in electrical and electronic engineering subjects at the University of Navarre. Several teams must accomplish a robotic project according to technical and economic restrictions imposed by professors. Each team gets points according to different assignments proposed throughout the semester.

Inter-university contests represent another very popular strategy to integrate competition in engineering teaching activities. For instance, paper [49] discusses the result of 15 years of experience with the Intelligent Ground Vehicle Competition (IGVC) in the Department of Electrical and Computer Engineering at the University of Detroit Mercy. Similarly, authors of [50] describe the experience of the University of Oviedo in the two

editions of the international competition MotoStudent and the impact on students. Finally, the basis of a project college competition for Electrical and Electronics engineering students is described in [51]. The proposed project competition ensured that students are equipped with the proper practical skills that are required by the industry.

2.5 Chemical Engineering

The Chem-E car experience is a clear example of a competition-based learning approach. It is an experience with a solid background in the Unites States and it has now become of interest for other countries in Europe or Asia. In this scheme, students work in a team to design, build and test a small-sized, inherently-safe and environmentally friendly car prototype powered by a chemical reaction [52]. The goal is that the designed car traverses a given distance and stops a maximum time of 2 minutes. There is a preliminary document with some instructions. The design, in particular its safety characteristics are defended by the team in front of a jury. Then, there is a real test of the prototype. According to the authors, their students develop teamwork, leadership, ability for autonomous work, capacity to apply knowledge to practice and skills in interpersonal relationships.

3. Analysis of the Parameters used in CBL Experiments

There are multiple configuration schemes for a competition-based learning. After matching the activities to the learning objectives, the configuration parameters must be considered. A learning technique is associated with several parameters that need to be decided on before putting in practice. They are the following ones:

- **Individual/Group.** A competition-based practice can be executed with individual students or in groups. When using the first approach, it is important to consider if it is more convenient to use alias so that they can compete anonymously. In this way, some frustration and anxiety may be reduced. In a similar way, we could opt for publishing or not the results in order to make this experience more comfortable for the students. With groups, the students feel that they are not so exposed, and alias are only useful as a gamification tool. With groups, it is important to note that we are combining collaborative and competition-based learning. Consequently, we should include the tools that make a fair distribution of tasks among the members of the group.
- **Selection of the winners.** For the whole competition or for every task, we have to identify the best solutions to proclaim the winners. Different criteria can be applied. Some proposals opt for focusing on the accuracy of the solution or the performance of the developed systems. Others, include a time-restriction, so it is important to get a good solution but fast. For all these options, clear metrics and rules for the evaluation must be explained to the students to avoid frustration. In [7], the students define their own rules and metrics. They even evaluate the work of other groups.
- **Sharing the solutions.** In some experiments, students can see the results of other students. This can be done for two main reasons. First, it could be used as a learning reinforcement. Students analyze other options so they can understand other designs, developments or approach. As an alternative, it is possible to share the solution for sequential task so that all students initiate the activity with the same start position.
- **Individual or sequential tasks.** A competition can be accomplished with only one task, maybe developed during several weeks, or as a sequence of activities. When implementing a sequence of competition-base tasks, they can be linked so that the solution of one activity is used in the following one. This approach may discourage those students who performed poorly in the first stages. Independent activities are preferred to avoid this negative effect.
- **Intrinsic/Extrinsic motivation.** In order to see the progress in the competition, students are usually associated to a score, whether it is public or not. The competition and its score could be related to a percentage of the final grade that the students get. This would be the case of using extrinsic motivation. Alternatively, there may not be any relationship between the score and the grade when intrinsic motivation is employed.
- **Supported by a technological platform.** The use of a software tool to support the competition reports four main advantages. First, it helps student to immerse themselves in learning, leading to an improved engagement. Secondly, it can be configured to set anonymous competitions, which may reduce the stress detected in face-to-face competition [9]. It also provides the flexibility to carry out the competition outside the class, which may be helpful when mobility restrictions are applied. Finally, some software tools are oriented to reduce the payload of implementing this technique [53].
- **Gamification.** Tailoring the activities as a game is an effective pedagogic tool to capture student interest, encourage active learning and motivate their participation. Game-learning is sometimes conducted altogether with competition as this technique promotes the student's motivation to

Table 1. Characterization of the analyzed CBL examples in engineering studies

Reference	Group	Gamified	Software	Motivation	Tasks	Sharing solutions	Criteria
[20, 25]	No	Yes	No	Both	Multiple	No	Performance
[4]	No	Yes	No	Both	Multiple	No	Achievement
[40]	No	Yes	Yes	Both	1	No	Accuracy, time
[39]	No	No	No	E	Multiple	No	Achievement
[7]	Yes	Yes	No	I	Multiple	No	Performance
[26]	Yes	Yes	No	Both	Multiple	No	Performance
[3]	Yes	No	No	Both	Multiple	No	Time
[36]	Yes	Yes	No	Both	Multiple	Yes	Achievement
[35]	Yes	No	Yes	E	Multiple	Yes	Achievement
[41]	Yes	No	No	Both	Multiple	Yes	Performance
[4]	Yes	Yes	No	E	Multiple	No	Achievements
[29]	Yes	Yes	No	E	Multiple	Yes	Achievements
[9, 31]	Both	No	Yes	I	Multiple	Yes	Correctness, time
[33]	Both	No	Yes	I	Multiple	No	Performance
[38]	Both	No	No	E	1	Yes	Presentation

try the activities harder. In fact, there are some experiences which outline the need for combining gaming and competition to foster the interaction with other players as the exclusive application of the game does not lead to an increased engagement [54].

Based on these parameters, we detail the features of several competition-based implementations in engineering degree curricula. They are presented in Table 1. We indicate: (i) if the experiment uses groups to compete, (ii) if it includes some gamification elements, (iii) if there is a software supporting the competition-based approach, (iv) if the motivation is intrinsic or extrinsic (represented with letter I or E respectively), (v) if there is only one task or multiple activities, (vi) if the students share the solutions once a competition phase has ended and (vii) the criteria to determine the winners of each competition phase.

It can be observed that most implementations rely on sequential tasks to complete the competition. It is not common to make them time-constrained, but some experiments have incorporated this restriction. There is not a clear trend for the group-based competitions, and we can still find some implementations with individual competitors. Although gamification is expected to improve students' engagement in the competition, it is not present in half of the experiments. This may be due to the complexity or workload that gamification could report to the lecturers.

4. Discussion

One of the main reasons of the application of innovative learning methods in higher education, and precisely in engineering degree programs, is the high number of dropouts and the lack of motivation [55]: students usually try to pass a subject without any interest in their performance and without considering it as an achievement of the learning outcomes. Thus, Competition Based Learning, as previously commented, is used in engineering degree courses to foster students' motivation and engagement and to try to avoid dropouts [2]. Consequently, in this paper the research results of several successful CBL experiments have been shown. They involve cases of application of this methodology in higher education. Most of those papers were published in the past decade. Some previous work has also been analyzed due to the important discussion they arose.

The first important concern about the reviewed bibliography is about the results of the experiments. All of them conclude that CBL was a meaningful technique to improve students' learning and consequently their marks [4, 33, 42]. Some works also point out that the main effect was the significant increase in student's engagement. It is obvious that, engagement, motivation and learning are closely related, so CBL appears to be a suitable method to increase students' motivation and hence improve students' performance and to avoid dropouts [12].

Moreover, taking into account the reviewed papers, it can be considered two main techniques to develop CBL in engineering subjects: those that used contest or competitions during the lessons time like [20, 22, 24, 25, 49, 50] and those that run the competition in other intervals of time [3, 7, 26, 27, 35, 42–44, 47]. Both approaches have shown important benefits to both students' motivation and engagement, and it could be difficult to determine which one is better.

However, when CBL is developed through an external contest or application in such a way that it allows students to compete with other students outside their own university, CBL itself has its own risks as stated in [56]. The authors remark that contest based on submitting some solutions (program codification) does not guarantee the learning process. They indicate that by the end of each phase of the competition, students should have access to good and detailed correct solutions and instructors should give the corresponding feedback to their students. Thus, the motivation and excitement of competition based on the submission of solutions must be always guided by an instructor, who should be oriented to improve students' competences in spite of the results of the competition. Moreover, it is necessary that lecturers monitor all the students during the competition to detect those that could be frustrated [13] because they usually lose the competition. In addition, lectures should reconsider if the pace of the competition has derived in an excessive demanding working load [14].

Another approach to CBL is gamification. In gamification, the competition is transformed into a game in which the mechanics are tailored to the learning and evaluation process of a subject. Thus, the students usually advance in that game with their work developing common tasks like doing exercises or solving problems [4]. Conversely to contest-based CBL, gamification approaches usually incorporate some rewards [4, 33]. Those rewards try to keep the students engaged in the process allowing them to interact with the game through minor improvements or prizes. In addition, in gamification, the achievement could be obtained during the game, not only when the student wins [40]. Therefore, it is possible to balance the difficulty of the task and the potential rewards to keep even those students with lower performance engaged. However, as it was stated in [54] achievements or badges could not be motivating for all the players, and it is important to design the game to also offer intrinsic motivations to the students. Besides, some papers that include an evaluation survey for the students about the CBL application show that students perceive the experience as very positive [5, 22, 24, 25].

Finally, another aspect that should be taken into account is that CBL and gamification require of an extra effort from the lecturers, who have to deal with their teaching activities and with managing the competition. Competition-related tasks have a significant workload as they are usually performed without a specialized or automatic tool [1]. Moreover, lecturers usually do not get any appreciation from University managers about applying these techniques to their lessons. This attitude makes CBL experiments not as common as they should be in higher education.

5. Conclusions

The reviewed bibliography shows that there are several meaningful examples where Competition-based learning has been applied successfully in higher education. The studied papers have shown that CBL is suitable for engineering degree programs in computer science, telecommunications systems, smart industry, electrical engineering and chemical engineering. In all the cases students show an increase in their motivation and their learning outcomes improved. It must be noted that CBL by itself could not be enough to improve students' motivation and performance. Thus, it is necessary that the lecturer or teacher guides and supervises the competition to detect those students that could be less motivated or even lost. In addition, lecturers should take care of those students who participate but they do not usually win any phase of the competition. For these students, lecturers should strengthen their learning with additional content, explanations or examples.

Therefore, CBL, an also gamification, are proved to be good to develop skills that are required in engineering subjects through competitions or games that keep students engaged during the course. However, the lecturers' workload increases because it is usual that they lack of an automatic tool that manages the competition and evaluation of the students' tasks. Thus, further efforts should be coordinated to generate effective and open-source software tools which could alleviate this workload in the lecturer.

As future work, the authors intend to apply an Artificial-Intelligence technique to derive some recommendation guidelines for the correct application of CBL in Engineering degree courses. New CBL experiments focused on gamification and on competency-guided learning will be designed and conducted for telecommunication engineering and electrical engineering degree courses.

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