Education for Chemical Engineers 45 (2023) 41–51

Contents lists available at ScienceDirect

Education for Chemical Engineers

journal homepage: www.elsevier.com/locate/ece

Gamification in thermal engineering: Does it encourage motivation and learning?

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ARTICLE INFO

Keywords:
Engagement
Gamification
Higher education
Learning method
Motivation
Thermal engineering

ABSTRACT

Gamification is considered as an approach to motivate and engage students in their learning process. An empirical study is carried out here on the use of gamification techniques in two engineering courses, in the field of Thermal Engineering, taught in two Spanish universities during several academic years. Both courses have similar syllabuses, and require the understanding and application of relatively complex concepts, related to Thermodynamics and Heat Transfer. The aim of this work was to increase studentś motivation and to help them in the process of assimilating and establishing key concepts related to these courses. Studentś satisfaction with the activity was assessed by means of surveys designed and proposed according to the Student Evaluation of Educational Quality (SEEQ) model, using a statistical package. The students were quite satisfied with the participation in the activity, the teamwork, the organization, and the grades. However, they considered that the learning of concepts was stronger in traditional classes. No significant differences were found between degrees or group size. Incorporating gamification techniques has proved to have a motivating effect on students, getting them involved in learning and in the development of the course.

1. Overview of problem

1.1. Challenges of STEAM careers

Nowadays, there is an upward trend in the demand for professionals with studies in Science, Technology, Engineering, Arts and Mathematics (so-called STEAM careers) (Morse, 2018). These experts will have to provide solutions to future challenges related to both scientific and technological innovation (Ortiz-Rojas et al., 2016). However, despite this trend, these careers face several obstacles such as the low number of students, the low success rate and the low percentage of women, in many cases (Markopoulos et al., 2015; Ortiz-Rojas et al., 2019). For this reason, both institutions and universities are looking for alternatives to recruit more students (Šćepanović et al., 2015). It is necessary to identify innovative teaching strategies that improve learning motivation taking into account the conjunction between motivation and education (Fernandez-Antolin et al., 2020; McClelland Pott et al., 2017) Among these strategies, gamification techniques, considered as the use of game elements in contexts not directly related to games, such as the educational sector, have attracted the attention of educators (de la Flor et al., 2020; Ortiz-Rojas et al., 2016; Rodríguez et al., 2018). Most of the studies published to date point out that gamification has two main objectives: to improve both student motivation and engagement (Kim, 2013; Laine and Lindberg, 2020; Ortiz-Rojas et al., 2019; Rodríguez et al., 2018). And, furthermore, if this technique is well designed and is used correctly, it also has great potential to improve the learning process (de la Flor et al., 2020; Dicheva et al., 2015; Rodríguez et al., 2018). It is a self-regulated learning model promoting individual cognitive development rather than traditional learning method (Fernandez-Antolin et al., 2020).

This paper presents an empiric study on the use of gamification techniques in technical courses with two main objectives. Firstly, to improve students' motivation and, secondly, to help in the assimilation and establishment of key concepts in these technical courses. Specifically, the gamification was applied to two courses, with similar syllabuses, taught in two different Spanish universities. On the one hand, the subject "Fundamentals of Thermal Engineering", which is taught in the Bachelorś Degrees in Industrial Chemical Engineering and Industrial Electronics and Automation Engineering at the University of Las Palmas de Gran Canaria. On the other hand, the subject "Thermal Engineering", taught in English in the Bachelorś Double Degree in Civil Engineering and Mining and Energy Resources Engineering at the University of

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https://doi.org/10.1016/j.ece.2023.07.006
Received 25 March 2023; Received in revised form 11 July 2023; Accepted 18 July 2023
Available online 22 July 2023

Oviedo. The study was conducted over 5 academic years, from 2015 to 2020.

1.2. Technical courses complexity

The curricula of Engineering careers have been modified according to the European Higher Education Area (EHEA). Due to these modifications, Spanish engineering schools have had to adapt various courses, in most cases, by reducing the number of teaching hours, and maintaining the syllabus and concepts almost in their entirety. This occurs in the courses analysed in this paper, "Thermal Engineering" and "Fundamentals of Thermal Engineering", which are taught for one semester and have a very broad content. In these courses, lecturers explain concepts about Thermodynamic, several devices and industrial cycles, as well as concepts about Heat Transfer including basic mechanisms and combinations thereof. These subjects are very extensive and there is little time available. In the previous engineering curricula, there were two courses, "Thermodynamics" and "Heat Transfer", one for each part and over the whole year. Furthermore, these courses, require students to understand and apply concepts of relative complexity.

In addition, some students can obtain the bilingual degree (specifically at the University of Oviedo), adding even more difficulty, since most of the students are not native English speakers. In order to motivate students and help them in the assimilation process and in fixing the key concepts in these subjects, the lecturers proposed to them a teaching innovation activity using gamification techniques.

1.3. Teaching innovation projects

The authors of this paper have been involved, since 2015–2016, in numerous teaching innovation projects, submitted and approved in internal calls at the University of Oviedo. These projects are an attempt to respond to the issues raised above and according to the University's strategy, the following objectives were established:

- To improve the teaching quality of technical courses through the new teaching-learning methodologies such as information and communication technologies, including gamification.
- To involve the students, encouraging their attendance to on-site lessons, capturing their attention and increasing both their participations in the course development and their motivation in the learning process. For this purpose, the lecturers proposed them an activity, in which they had to develop elements and rules of games, to improve the assimilation and fixation of key concepts in a pleasant and attractive way.
- To promote the development of students' transversal competences such as the use of appropriate oral language in the presentations (in Spanish and English); the use of innovative technologies in the learning process such as gamification; the creation of resources, such as the challenges posed in the games; the correct use of the bibliography, etc.
- To improve the interaction and communication among students and also, among students and lecturers during the activity.
- To promote the coordination and collaboration among universities. The University of Oviedo and the University of Las Palmas de Gran Canaria have been collaborating closely in these teaching innovation projects. Also, both universities have established guidelines to continue working together in both teaching and research projects.

2. Overview of issues and literature

2.1. Related work

Gamification, defined as "the use of game design elements in non-game contexts", is a relatively recent technique (Deterding et al., 2011). It is increasingly being applied in sectors such as business and marketing, to influence and modify people's behaviour (Dicheva et al., 2015; Subhash and Cudney, 2018). In the educational sector, gamification techniques are used as pedagogical innovation measures, mainly to improve both students' motivation and engagement (Álvaro-Tordesillas et al., 2019; De et al., 2014; Subhash and Cudney, 2018). Recently, Laine and Lindberg, published a comprehensive synthesis about gamification used to raise and maintain the motivation in difficult tasks such as the technical subjects (Kim, 2013). So far, most of the papers point out that this technique is still very young in this field, especially in higher education (Antonaci et al., 2017; De et al., 2014; Dicheva et al., 2015; Markopoulos et al., 2015). Also, there are few articles on student's intentions to use these techniques, as Chung et al. point out (Chung et al., 2019). They explore the main factors influencing the acceptance of gamification in higher education (Chung et al., 2019).

At the university level, many of the articles published on gamification focus on the application of these techniques in courses related to software development and new technologies. Some of them describe the methodology used (Alhammad and Moreno, 2018; Iosup and Epema, 2014; Kosa et al., 2016). In other cases, the results show a significant improvement in both students' participation and motivation (Barata et al., 2013a, 2013b; Lambruschini and Pizarro, 2015; Ninaus et al., 2020). And, others, such as Rojas-López et al., indicate that gamification contributes to improve the students ́engagement in successfully solving difficult tasks (Rojas-López et al., 2019). Also, some studies have observed a real impact of gamification on students' academic performance in degrees such as Physical Education (Ferriz-Valero et al., 2020). Other publications analyse the use of gamification to enhance learning in online courses or careers, which currently are very fashionable (Antonaci et al., 2017; Borras-Gene et al., 2016; De-Marcos et al., 2017; Urh et al., 2015). More recently, other papers apply these techniques to engineering studies (Azizan et al., 2018; de la Flor et al., 2020; McClelland Pott et al., 2017; Rodríguez et al., 2018). In these articles, the improvement of student motivation and learning outcomes in complex subjects such as "Kinetics of Chemical Reactions", Fluid Mechanics, Organic Chemistry and Heat Transfer are studied using gamification techniques. In all cases, the results show a significant improvement compared to traditional techniques and high level of student acceptance.

However, numerous papers point out the need for more empirical studies on these techniques in higher education and more specifically, in technical careers such as industry, mining, forestry, etc., analysing the real impact of the use of gamification in the learning process and using an appropriate evaluation (Dicheva et al., 2015; Kim, 2013; Markopoulos et al., 2015; Ortiz-Rojas et al., 2019,). Fernández-Antolin et al., highlight that students of these technical careers prefer non-traditional learning methodologies, considering them as active elements in the learning process (Fernandez-Antolin et al., 2020). Some articles explain that the shortage of these studies can be due to different reasons. Among them, Dicheva et al. 2015, highlight that the lecturers of these degrees believe that they need extensive knowledge in software development, extensive computer support and resources, and a lot of time to design, develop and implement the game, since gamification is a term directly related to video games or digital games and not to traditional games (Dicheva et al., 2015). In a review, Subhash and Cudney analyze more than 40 papers related to gamification (Subhash and Cudney, 2018) and only Wiggins use non-digital games in a communication faculty (Wiggins, 2016). Non-digital games, which do not have the aforementioned requirements, could be a real alternative to video-games for lecturers of the abovementioned engineering studies, who wish to implement these techniques in their lessons. Azizan et al., design a "board game" for "Reaction Engineering" where other skills such as teamwork and creativity are developed (Azizan et al., 2018).

2.2. Novelty of the paper

In this paper an empirical study is carried out about the application of gamification in technical courses in engineering degrees, taught in two different Spanish universities. Different games, have been designed, along with their elements and rules. In addition, students from both universities have been involved in the design, development and implementation of the games. The results obtained have been evaluated by means of surveys designed and proposed according to the Student Evaluation of Educational Quality (SEEQ) model (Marsh, 1984), using a statistical package. The interest of this work has been commented above in the sections on the challenges and complexity of the technical courses. Its novelty has been highlighted in the analysis of the state of the art. On the one hand, the scientific articles about the use of gamification in technical careers, apart from computer science and telecommunications, (such as Industrial Engineering Degrees) are scarce. And, on the other hand, none of these articles use the SEEQ survey model to analyse the satisfaction and motivation of students with the application of the gamification.

3. Discussion of implementation

3.1. Design of the gamification activity

In parallel with the development of the courses, the lecturers presented the project to the students, indicating that they had to perform a double task:

- To design, develop and implement a game (or board for a board game) related to the subject, and the rules of the game.
- To pose challenges in the form of questions and problems related to the main concepts of the course.

On the one hand, this approach makes it possible to encourage students to be more involved and participative, and to stimulate their interest in assimilating the concepts and applying them, since they have mastered the subject to the point of being able to develop their own theoretical questions and practical exercises. On the other hand, it encourages the use of different tools (electronic devices, gamification techniques, design tools, etc.).

The groups of students who participated in the project were the students of the "Fundamentals of Thermal Engineering" course taught in the Bacheloŕs Degrees in Industrial Chemical Engineering (IChE) and in Industrial Electronics and Automation Engineering (IEAE) at the University of Las Palmas de Gran Canaria, and those of the "Thermal Engineering" course of the Bacheloŕs Double Degree in Civil Engineering, and Mining and Energy Resources Engineering (CE-MERE) at the Polytechnic School of Gijón at the University of Oviedo.

For the development of the project, students were divided into groups of 2–3 people, depending on the total number of students in each course. Each group designed, developed, and implemented a game related to the key concepts, as well as the rules of the game. The lecturers evaluated the activities, making corrections where necessary, and suggesting improvements in both format and content. Once the game had been created, teams of students were organized to participate in a game session, supervised and moderated by a lecturer appointed as a responsible for each specific session. Each challenge in the game was given a score according to its difficulty and the teams received different scores depending on the challenges they solved. The team with the highest number of points at the end of the session was the winner of the game, demonstrating a greater mastery of the course contents.

In the initial outline of the project, it was proposed that the activities to be developed would be essentially face-to-face. This was possible in the first academic years of the project implementation, from 2015–2016 to 2018–2019, and in the first semester of 2019–2020 in both universities. Nonetheless, since the "Thermal Engineering" course of the double Degree (CE-MERE) (English group) at the University of Oviedo is taught in the second semester, and due to the pandemic, the activities carried out in that period were all online during the academic year 2019–2020. For this semester, the game was designed, and the challenges were developed, but it was not possible to carry out the face-to-face session of the game in the classroom.

3.2. Learning materials

Students and lecturers were provided with learning materials, in both Spanish and English, for all the topics of the two courses. These materials had been developed in previous years and were accessible to students in the "Virtual Campuses" (Moodle courses) of the two universities involved in this study and from the beginning of the teaching periods of each academic year. For both the University of Oviedo and the University of Las Palmas de Gran Canaria, the materials were available in Spanish and English languages, and they consisted of:

- Power Point presentations explaining the theoretical content.
- Short videos (between 10 and 15 min) to present some concepts in a concise way and applied to simple cases.
- List of short questions on each topic with their answers, to reinforce the theoretical concepts.
- Problem statements for each topic and their solutions which can be used to address the challenges.
- Mandatory and recommended bibliography.

Some of the learning materials mentioned above were used by the teaching staff as a support tool in the lectures and classroom practice. The rest of the documentation was designed to encourage the students' capacity for autonomous work.

3.3. Work plan

As the project was carried out in two different universities and the courses involved were taught in different semesters, a similar work plan was followed in both cases, although deferred in time. This plan is shown schematically in Fig. 1, consisted of the following steps:

1. Kick-off meeting (week 1 of the semester). The lecturers involved from both universities had a first synchronous videoconference

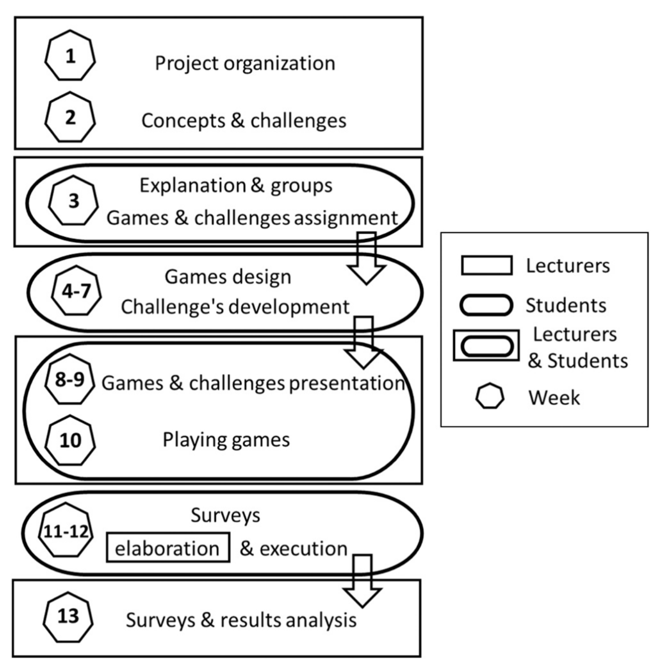


Fig. 1. Work plan of the gamification activity.

meeting to start the project and to organize and allocate the tasks to be developed by each group (students and lecturers).
2. Second online meeting, also synchronous, of the teaching staff from both universities (week 2 of the semester). The teachers defined the concepts of the course content to be included in the games. These concepts would serve as a basis for the challenges to be proposed.
3. Face-to-face meetings with the students (week 3 of the semester). Lecturers from each university explained the project to the students. Groups of students interested in participating in the project were organized, since involvement in the project was not compulsory.
4. Design, development and implementation of the games and their rules by the students (weeks 4–7 of the semester). The student groups distributed the work based on the learning materials and the bibliography available in the Moodle courses. The students held several working meetings to share their knowledge and ideas and to discuss aspects of the game design and its rules.
5. Review of the studentś work (weeks 8 and 9 of the semester). The lecturers had group tutorials with the students in which the latter presented the games they had developed, their rules and the different challenges. The lecturers solved doubts, evaluated the games and challenges, and suggested changes and/or improvements.
6. Implementation of the game in the classroom (week 10 of the semester). Both lecturers and students of each course participated in one or two game sessions, using the materials developed in the previous tasks. The students who had not designed the game were divided into teams and during this session they had to solve the challenges set by the lecturers or their classmates. According to the rules of the game, each challenge had a different score. The team with the highest total score was the winner of the session.
7. Preparation and completion of surveys (weeks 11 and 12 of the semester). Lecturers prepared surveys to measure the students' level of satisfaction with this activity, and at the end of the semester, the surveys were given to students to complete.
8. Final meetings with the lecturers (week 13 of the semester). The results obtained were analysed after all the tasks had been completed in order to know their level of satisfaction with the project.

3.4. Games developed by the students

The games developed by the students were similar and comparable. Some were student initiatives, such as Trivial, the traditional Sink the Fleet game, Jeopardy, and Twister. Others were suggested by the lecturers, such as Kahoot, a Scape-room, or a board game in which the board represented the Rankine cycle, one of the thermodynamic cycles studied in the courses. Fig. 2 shows, as an example, a Rankine cycle board with rules elaborated by the CE-MERE group at the University of Oviedo during the 2018–2019 academic year, Fig. 2. (a), and one of the classroom game sessions of the IChE group at the University of Las Palmas de Gran Canaria during the 2019–2020 academic year, Fig. 2. (b).

3.5. Design and implementation of the satisfaction survey

3.5.1. Samples

Table 1 shows the samples, including the number of students who participated in the study and those who completed the satisfaction survey in the three Degree programs during the academic years under study.

3.5.2. Survey

A survey was designed to obtain the students' opinion as objectively as possible. The design of the survey followed the Student Evaluation of Educational Quality (SEEQ) model (Marsh, 1984). This adaptation consists of 21 questions grouped into 9 categories:

1. Learning/Value
2. Enthusiasm
3. Organization
4. Group interaction
5. Individual rapport
6. Breadth of coverage
7. Examinations/Grading
8. Assignments
9. Workload/Difficulty

Most of the questions were scored on a Likert-type scale from 1 to 5. There were also three open-ended questions in which students were free to give their opinion on the advantages and disadvantages of this learning method and to make suggestions for its improvement.

The survey was subjected to a reliability test using Cronbach's α internal consistency coefficient (Cronbach, 1951). This test is used when a second application to the same group of subjects is not possible, and when the answers to the questions have more than two values, for example, in an attitude scale with Likert-type responses. It was found that the questionnaire presented in this study has an overall Cronbach's coefficient of 0.914, and its reliability is considered adequate according to Barrios and Cosculluela, because it ranges between 0.7 and 0.95 (Barrios and Cosculluela, 2013).

3.5.3. Procedure

The surveys were distributed following a homogeneous protocol in all Degrees during the academic years under study. At the University of Las Palmas de Gran Canaria they were posted on the Moodle courses at the end of the semester, after the exams had been taken and marked. The surveys were anonymous, in order to ensure transparency and confidentiality. Students were encouraged to participate by explaining the importance of their answers in the development of this study. At the University of Oviedo, where the group of students was small, the survey, also anonymous, was given on paper, which also ensured the confidentiality of the responses.

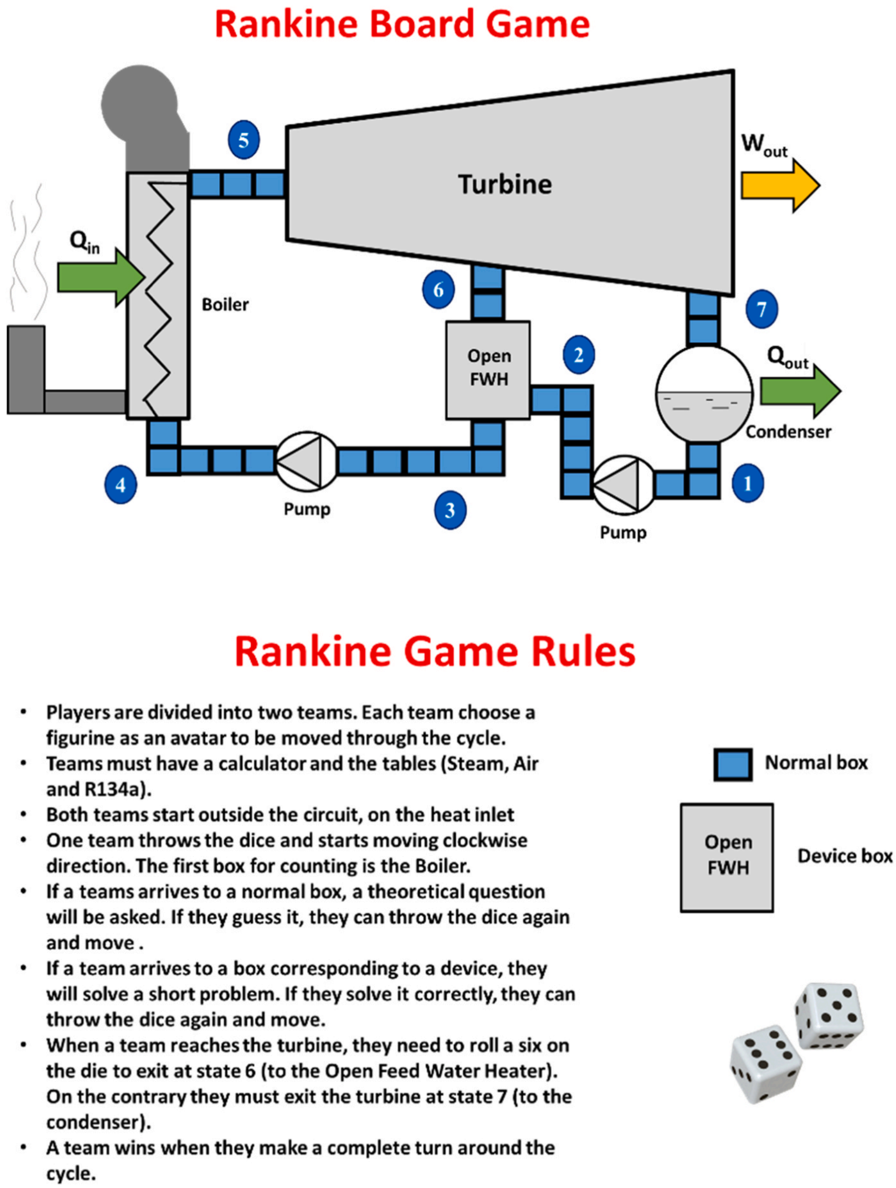
4. Discussion of impact

4.1. Student evaluation according to satisfaction surveys

The survey on student satisfaction with the gamification activity was analysed by descriptive statistics, using the Statistical Package for the Social Sciences (SPSS) software. Each of the questions was considered as an isolated variable. All variables were characterized as qualitative: some of them nominal (7, 8, 10, 21) and the others ordinal. In order to standardize the analysis, the value scales of the ordinal variables were transformed into continuous numerical values, from 1 to 5, and their distribution was tested using the Kolmogorov-Smirnov test. In all cases, the value of the test Z-statistic was in the interval 0.162–0.386, with an asymptotic significance (bilateral test with the corrected Lilliefors method) of 0.000–0.001, clearly below 0.05, rejecting the hypothesis of normal distribution. Therefore, non-parametric inferential statistics were used for comparisons between the groups.

A total of 172 surveys were collected. Eight of these had missing values for most of the questions as the students had not been directly involved in the development of the activity. Table 2 shows the results of the descriptive analysis: the number of valid cases, mean, median, mode, standard deviation, and variance.

In all the categories, the average score was higher than 3, except for the question "With this activity I have been able to learn more than simply going to class", which shows an average value of 2.89. This indicates that the students think that the learning of concepts is somewhat greater in traditional classes than in the gamification activity. This assessment is supported by the result of the "Learning" category, where both the mode and median are 3. However, students are quite satisfied with having participated in the activity, with the teamwork, the organization and the grades obtained (mode of 4). In addition, the activity



(a) Rankine cycle board and rules.

(b) Classroom game session.

Fig. 2. (a) Rankine cycle board and rules; (b) Classroom game session.

Table 1
Samples of students who participated in the study and completed the satisfaction survey.

Degree	Students enrolled	Students examined (%)	Passing students (%)	Students Surveyed (%)
IEAE	245	75.5	47.7	44.9
IChE	110	72.7	45.4	40
CE-MERE	20	100	98	90

has increased their interest in learning the subject (mode of 4). The questions about the teacher's attitude towards the pupil were highly rated with a mode of 5. In the "Workload/Difficulty" section, a mode of 3 was obtained, which indicates that the activity did not involve any greater effort or workload than other curricular activities. Thus, one of the objectives proposed in the design of this activity, namely to increase student motivation, is considered to have been achieved.

Fig. 3 shows the average values per category. It is clear that the average rating of the students in all categories is between 3 (satisfied) and 4 (fairly satisfied). The maximum value corresponds to the category of personal attitude (3.86) and the minimum to that of workload and difficulty (3.22).

Below there is a graphical breakdown of student satisfaction with participation in the activity by category (Fig. 4). For ordinal questions, the graphs show the percentage of students and the corresponding satisfaction rating standardized on the scale: not at all (1), a little (2), normal (3), quite a lot (4) and very much (5). Nominal questions are detailed in percentage of students who chose this option.

In the "Learning" category, 35 % of the students were moderately satisfied with the question on whether the development of the activity had helped them to understand the content of the subject, but 41.5 % were between fairly satisfied and very satisfied (4 + 5). Regarding the understanding of the concepts of the subject during the development of the game in the classroom, 23 % of the students were not very satisfied. The highest level of satisfaction was observed in the category "Enthusiasm", where 60 % of the students were between fairly and very satisfied (4 + 5) with their participation in the activity. The organization of the activity shows that 64 % (4 + 5) of the students knew from the beginning what the activity consisted of, and almost the same proportion found it rather or very easy to find the material. Almost 90 % of the students considered that the course notes and materials were enough to prepare the activity. The interaction with the group is rated very positively: 60 % (4 + 5) of the students found the teamwork quite or very helpful for a better understanding of the concepts. And more than 90 % of the students were involved in the teamwork: just 2 students had to do the work alone and another 2 students reported that their third classmate did not collaborate in the work. Regarding the category "Breadth of knowledge", 83 % were fairly to very satisfied (4 + 5) that their initiative was accepted by the teacher, but only 27 % considered that this activity helped them fairly to very much (4 + 5) in the acquisition of other concepts. "Attitude" shows that 8 % of the students were taking the subject for the first time, of which 12 % had enrolled before, but had never taken the exam. The attitude of the teacher was also rated very positively, 83 % thought that the teacher was between fairly and very helpful (4 + 5) in solving their difficulties during the activity.

47 % of the respondents commented that the activity had increased their interest in the subject between quite a lot and very much (4 + 5). 70 % of the students (3 + 4 + 5) expressed that the mark for this activity was fair and adequate, and 44 % (4 + 5) considered that the weight of this activity in the final mark was appropriate. However, 27 % of students (1 + 2) were not very satisfied with the weight of this activity in the final mark.

Regarding the workload and difficulty of the activity compared to other activities in other subjects, almost 60 % of the students found it normal (3): 80 % of them spent less than 10 h on it.

Table 2
Descriptive analysis of the questions in the student satisfaction survey.

Questions	Valid cases	Mean	Median	Mode	Standard deviation	Variance
LEARNING/VALUE						
Understanding of content during the development of the activity.	164	3.54	3	3	1.174	1.377
Understanding of content during the development of the game in the classroom.	164	3.23	3	3	1.042	1.087
Effectiveness of this learning method.	172	3.39	3	3	1.003	1.006
ENTHUSIASM						
Satisfaction in participating in the activity.	172	3.55	4	4	0.952	0.907
ORGANIZATION						
From the beginning we have been accurate about what the activity consisted of.	164	3.70	4	4	1.203	1.446
It was easy for you to find the material to carry out the activity.	164	3.61	4	4	1.050	1.102
GROUP INTERACTION						
Teamwork has helped me to understand the subject better.	164	3.69	4	4	1.142	1.304
INDIVIDUAL RAPPORT						
The activity has increased my interest in learning the subject.	172	3.22	3	4	1.124	1.263
The teacher was very helpful in answering our questions.	164	4.50	5	5	1.000	1.000
BREADTH OF COVERAGE						
The teacher has accepted the student's initiative.	164	4.28	4	5	1.031	1.063
This activity has helped me to acquire additional knowledge.	164	3.08	3	3	1.228	1.507
EXAMINATIONS/GRADING						
The grade obtained for this activity was fair and appropriate.	164	3.92	4	4	1.317	1.736
The weighting of this activity in the final grade is appropriate.	164	3.42	4	4	1.360	1.850
ASSIGNMENTS						
I have found the class notes/explanations useful for this activity.	164	4.06	4	4	1.170	1.368

(continued on next page)

Table 2 (*continued*)

Questions	Valid cases	Mean	Median	Mode	Standard deviation	Variance
With this activity I have been able to learn more than simply going to class.	164	2.89	3	3	1.063	1.130
WORKLOAD/DIFFICULTY						
Difficulty of this activity compared to others.	172	3.14	3	3	1.199	1.437
Workload.	172	3.31	3	3	1.009	1.018

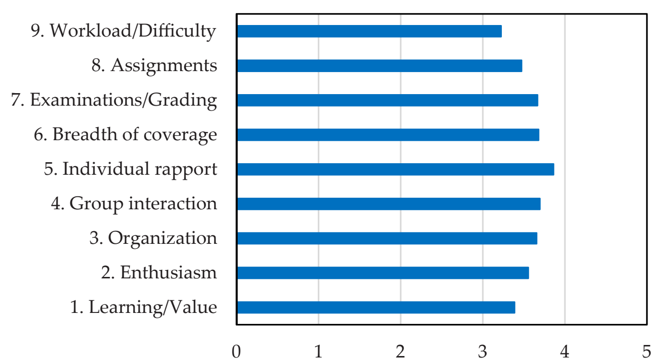


Fig. 3. Average values by category.

Another objective of our work was to carry out a collaborative study between two Spanish universities, the University of Las Palmas de Gran Canaria and the University of Oviedo. This activity would allow us to compare of the results according to the size of the groups. At the University of Las Palmas de Gran Canaria, the activity took place in the "Fundamentals of Thermal Engineering" subject taught in the Degree Industrial Chemical Engineering (IChE), which corresponds to a medium-sized group, with less than 25 students enrolled, and in the Industrial Electronics and Automation Engineering (IEAE), which can be considered a large group, with around 50 students enrolled each year. At the University of Oviedo, the subject "Thermal Engineering" of the double Degree in Civil Engineering and Mining and Energy Resources Engineering (CE-MERE) enrolled between 4 and 11 students each year, which is a small group.

A comparative analysis was carried out by degree (i.e. by group size). Non-parametric statistical tests were used for the analysis, as the distribution was far from normal. As hypothesis 0 it was assumed that the distribution was the same across the degree categories.

In the first academic years (from 2015–2016 to 2018–2019), it was possible to make a comparison between the results of the 3 degrees. Table 3 shows the mean values grouped by the different categories of the small (CE-MERE), medium (IChE) and large (IEAE) groups. As 3 samples were available, the Kruskal-Wallis test (1-way ANOVA) and the Median test for independent samples were used. In the Kruskal-Wallis test, H-statistic values between 1.322 and 0.659 were obtained, with corresponding significances between 0.153 and 0.465 (Table 3). For the median test, test statistic values ranged from 4.123 to 1.505, with asymptotic significances between 0.153 and 0.465 (Table 3). With a significance greater than 0.05 in all cases, both tests recommend retaining hypothesis 0.

For the 2019–2020 academic year, the comparison was limited to the medium and large groups. As explained above, the small group, whose classes were taught in the second semester, was affected by the confinement decreed due to the COVID'19 pandemic. Although the students had prepared the activity, it was not possible to carry it out in the classroom and, therefore, they did not participate in the surveys. The other two degrees were not affected by this situation because the subject was taught in the first term. As there were only 2 independent samples, the Mann-Whitney U-test and the Median test were used. The Mann-Whitney U-test yielded U-statistic values between 85 and 129, with corresponding significances between 0.068 and 0.736 (Table 3). For the median test, test statistic values ranged from 1.245 to 0.007, with asymptotic significances between 0.237 and 0.869 (Table 3). Again, with significance greater than 0.05 in all cases, both tests recommend retaining hypothesis 0.

Therefore, in the given academic years, it was found that the differences between the degrees, i.e. those due to the size of the groups, were not statistically significant.

In order to obtain a more visual qualitative comparison, Fig. 5 shows the mean values of the scores corresponding to the different questions grouped by category, for the three degrees under study. The graph does not show very significant differences between the degrees, as the statistical analysis revealed. However, there are some details that are worth commenting on.

First, it is noteworthy that higher satisfaction values are observed in the first three academic years than in 2019–2020. There is no known reason that could justify such a difference, other than intrinsic reasons for the group members. At the university, it is well known that students are more motivated in one year than in another, perhaps simply because the interaction between them is better, as evidenced by the high scores in the categories " Group Interaction" and "Individual rapport" obtained for all degrees in the first period. It might have been expected that the highest scores in the "Learning" and "Enthusiasm" categories would have been obtained by the small group, CE-MERE double degree, since the low number of students might have facilitated learning and satisfaction. However, the highest values were obtained by the medium group, IChE degree. In most of the categories and for the different academic years, the lowest average satisfaction scores were presented by the large group. IEAE degree, except in the categories of "Assignments" and "Workload/ Difficulty", where their appreciation was that the difficulty of this activity was medium compared to other tasks in other subjects.

4.2. Comparison of the results with technical courses without gamification

Table 4 shows relevant information for analyzing student satisfaction by comparing courses in which gamification techniques were applied with similar courses in which gamification techniques were not applied.

This table shows some of the results of the institutional satisfaction surveys carried out at the University during the years of the study. It includes the results of the subject of Fundamentals of Thermal Engineering taught in the degree of Industrial Electronics and Automation at the University of Oviedo, where gamification techniques were not applied, and the same subject, of the same degree, at the University of Las Palmas de Gran Canaria, where gamification techniques were applied. These courses were taught by the same professors who are the authors of this work. The average number of students in the courses without gamification was 65, of which an average of 46 answered the questions. In the courses with gamification, the average number of students was 78, with an average of 58 answering the questions.

From the general values of the institutional surveys, four items were extracted:

1. I feel satisfied with what I have learned in this subject.
2. I feel satisfied with the usefulness of the training received for my professional future.
3. The different tasks performed facilitate the achievement of competencies.
4. The teacher proposes activities to favor autonomous learning.

On a scale of 0–10, it is observed that the introduction of

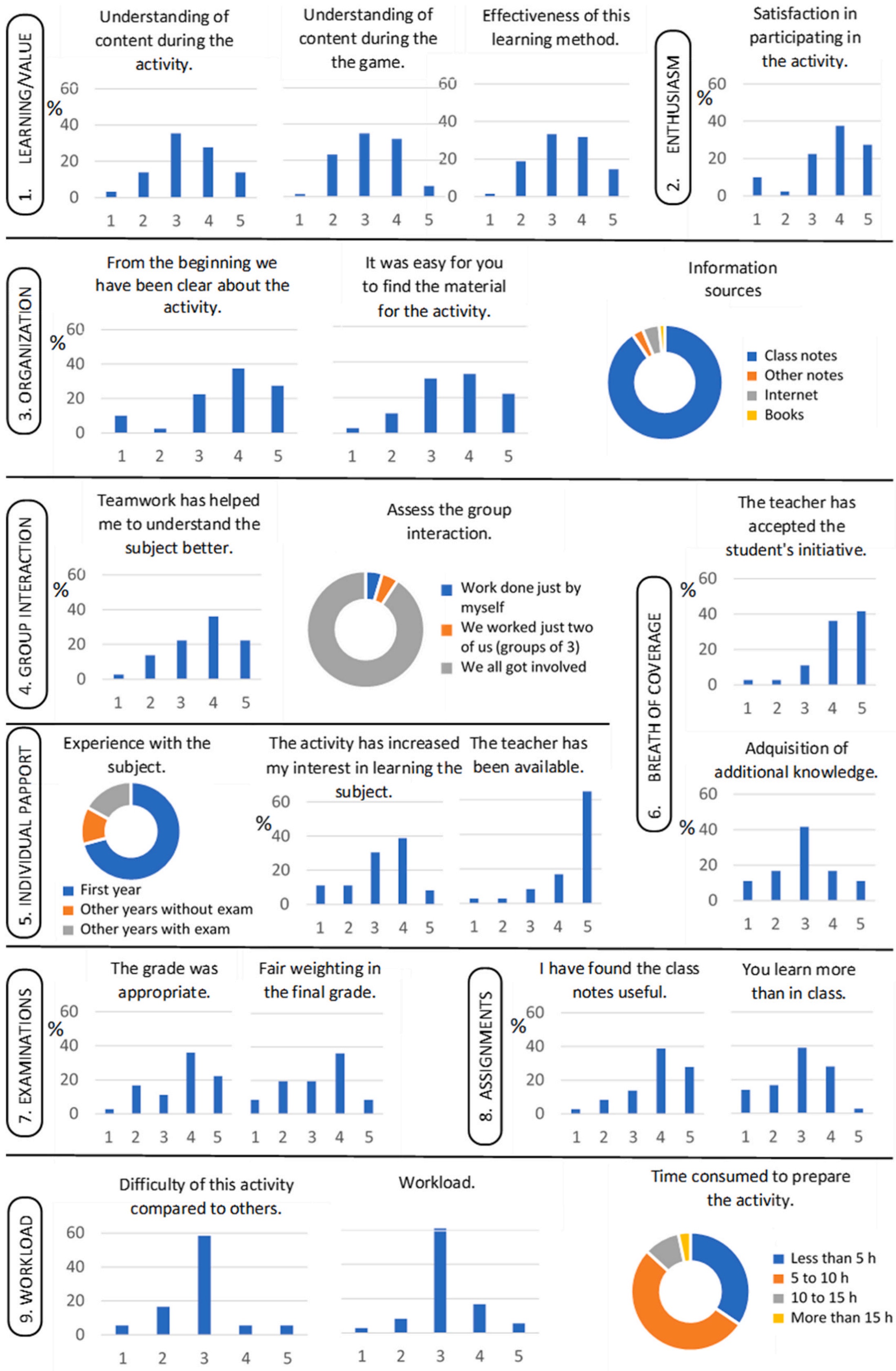


Fig. 4. Satisfaction of the students in participating in the activity by categories and questions.

Table 3
Mean values of the student satisfaction surveys with the gamification activity, by course and degree. Comparison and asymptotic significance.

2015–2016 to 2018–2019					
Categories	IC-IRME	IChE	IEAE	Median Significance	Significance ANOVA
1. Learning/ Value	3.88	4.38	3.26	0.286	0.298
2. Enthusiasm	4.20	4.90	4.00	0.453	0.465
3. Organization	4.75	4.65	3.97	0.375	0.396
4. Group interaction	4.75	4.93	4.89	0.315	0.337
5. Individual rapport	5.00	4.78	4.74	0.386	0.395
6. Breadth of coverage	4.00	4.62	4.37	0.274	0.288
7. Examinations/ Grading	4.50	4.11	3.82	0.273	0.283
8. Assignments	4.20	3.76	4.12	0.142	0.153
9. Workload/ Difficulty	3.00	3.02	3.25	0.296	0.318
2019–2020					
Categories		IChE	IEAE	Median Significance	Significance Mann-Whitney
1. Learning/ Value		3.39	3.31	0.694	0.546
2. Enthusiasm		3.91	3.54	0.887	0.366
3. Organization		4.09	3.40	0.368	0.068
4. Group interaction		3.82	3.64	0.835	0.735
5. Individual rapport		4.14	3.74	0.521	0.365
6. Breadth of coverage		3.86	3.60	0.869	0.555
7. Examinations/ Grading		4.09	3.48	0.519	0.196
8. Assignments		3.86	3.30	0.237	0.736
9. Workload/ Difficulty		2.86	3.38	0.639	0.314

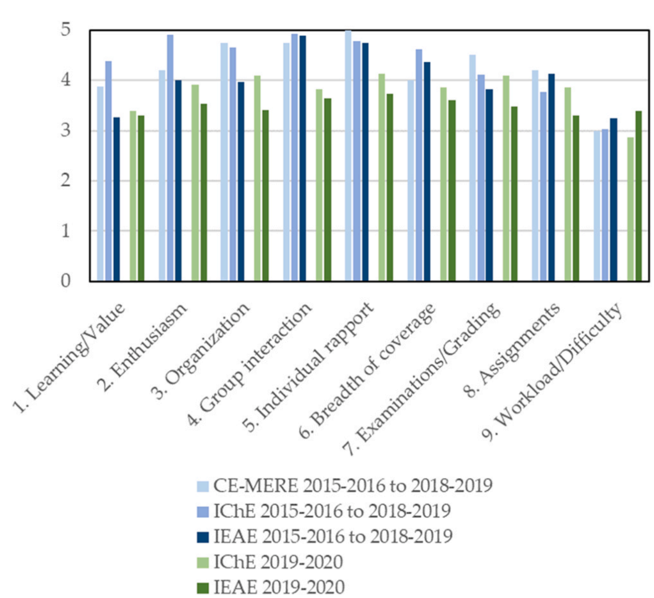


Fig. 5. Average values of the survey scores for the different categories, for the three Bachelor studies.

gamification activities in the classroom has increased student satisfaction with what they have learned in the subject by more than one point over the years of the study. Students, in general, also consider that gamification activities facilitate the achievement of competencies and autonomous learning.

4.3. Comparison with the literature

Table 5 shows a comparison of different articles related to gamification that have been published since 2018 in order to discuss the advantages and disadvantages of the present work with respect to these studies. All of them are empirical studies. For the comparison, the following items have been considered: learning techniques, duration of the study, use of digital resources, face-to-face, on-line or mixed modality, multilingual materials, analysis of concepts assimilation and analysis of motivation.

The study presented in this paper is the one with the longest duration of all of them (5 academic years), as opposed to the 3 or less academic years of the rest of the articles. This implies that the results of this study are more reliable and significant than those of the literature.

The techniques used in the different studies are diverse. Most use gamification exclusively, while some combine gamification with other approaches. In particular, the present study links gamification with cooperative learning. The article by Rodriguez et al., 2019 mixes gamification techniques with flipped classroom. This combination is very interesting, but it involves a much greater effort for both teachers and students and should be done in phases. That is, once students are familiar with the flipped classroom methodology, the addition of gamification makes sense. Introducing both methodologies at the same time can have a negative effect on students, as it represents a big change from traditional methodologies. All the studies use digital resources, something essential in the current historical moment, and most of them use mixed resources, both face-to-face and online. Significantly, none use exclusively face-to-face methodologies. Only 3 of the articles focus on learners of different languages, including the present study.

Regarding the influence of learning techniques on motivation and concept assimilation, all studies analyze the effect on concept assimilation with good results. Most of them, including the present study, also analyze the influence on students' motivation positively.

5. Conclusions

This article analyses the use of gamification in improving student motivation, on the one hand, and in assimilating and fixing of key concepts in technical subjects, on the other. These tools have been applied to two subjects in the field of Thermal Engineering, with similar syllabuses, taught at the University of Oviedo and the University of Las Palmas de Gran Canaria, during several academic years (from 2015-2016 to 2019–2020). This activity has been developed within the framework of Teaching Innovation Projects, where the involvement of students in the design, development and implementation of the games has been achieved. The results obtained were evaluated by means of surveys designed and set up according to the SEEQ model, using the SPSS statistical package.

The results of the satisfaction surveys indicate that students are quite satisfied with the participation in the activity, the teamwork, the organization, and the grades obtained. Moreover, this activity has increased their interest in learning the subject and has not involved any greater effort or workload than other curricular activities. However, they consider that the learning of the concepts is greater in the traditional classes than in the ones where gamification was used.

In terms of ratings by categories, enthusiasm and interaction with the group were rated most highly, with 60 % of students being fairly to very satisfied. The teacher's attitude was also highly rated: 83 % of the students thought the teacher was fairly to very available.

In terms of the comparative analysis between the two universities, no statistically significant differences were found between the degrees, and therefore the size of the groups in the years analyzed.

Declaration of Competing Interest

The authors declare that they have no known competing financial

Table 4
Satisfaction of the students of Fundamentals of Thermal Engineering of the Industrial Electronics and Automation degree with the autonomous learning of the subject in courses with and without gamification. Scale from 0 to 10.

Item	Gamification activities	2015–16	2016–17	2017–18	2018–19	2019–20
1. I feel satisfied with what I have learned in this subject.	*Without*	*5.8*	*5.1*	*4.4*	*7.2*	*7.4*
	With	**6.7**	**6.6**	**7.8**	**8.7**	**8.9**
2. I feel satisfied with the usefulness of the training received for my professional future.	*Without*	*5.6*	*5.1*	*5.0*	*6.9*	*7.2*
	With	**5.8**	**5.3**	**5.0**	**7.2**	**7.4**
3. The different tasks performed facilitate the achievement of competencies.	*Without*	*5.3*	*5.2*	*4.9*	*6.5*	*6.3*
	With	**7.0**	**7.8**	**8.6**	**9.1**	**9.0**
4. The teacher proposes activities to favor autonomous learning.	*Without*	*5.5*	*5.1*	*4.8*	*7.3*	*7.4*
	With	**6.9**	**7.7**	**8.7**	**9.2**	**9.2**

Table 5
Comparison with the literature.

Reference	Learning techniques	Duration of the study	Use of digital resources	Modality: Face-to-face, on-line or mixed	Multilingual materials	Analysis of concepts assimilation	Analysis of motivation
This work	Gamification/ cooperative learning	5 academic years	Yes	Mixed	Yes	Yes	Yes
Rodríguez et al., 2018	Flipped classroom /peer learning material/ gamification	1 academic year	Yes	Mixed	No	Yes	Yes
Azizan et al., 2018	Gamification/ cooperative learning	1 semester	Yes	Mixed	No	Yes	No
de la Flor et al., 2020	Escape lab-room	3 academic years	Yes	On-line	No	Yes	Yes
Nunes da Silva Júnior et al., 2021a	Gamification	1 academic year	Yes	On-line	Yes	Yes	No
Nunes da Silva Júnior et al., 2021b	Gamification	2 academic years	Yes	Mixed	Yes	Yes	No
Monnot et al., 2020	Escape game activities	1 semester	Yes	Mixed	No	Yes	No
Martín-Sómer et al., 2021	Kahoot!	1 academic year	Yes	On-line	No	Yes	Yes
Chans and Portuguez Castro, 2021	Gamification	2 academic years	Yes	On-line	No	Yes	Yes

interests or personal relationships that could have appeared to influence the work reported in this paper.

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