Improving the Teaching-Learning Process in Engineering through a Game-Based Web Support System: Edutrivias

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Abstract. In this article, the authors propose the use of trivia games as a tool to support the teaching-learning process in engineering, and present results of the use of trivia games in the Chilean university context. Specifically, we describe a web system called Edutrivias (http://edutrivias.cl) which allows the interaction between teacher and engineering students through game-based learning. Edutrivias allows teachers to create trivia games that can be played by students, as many times as they want, within determined goals and a period of time defined by the teacher. Every time a student plays a trivia, he/she receives information regarding his/her level of progress. At the same time, the teacher can verify the participation of the students, as well as the level of the group and individual advancement. From a pedagogical point of view, teachers deliver knowledge through the trivia games, while the students "play" trivia games to acquire, increase and apply their knowledge through an intermittent reinforcement learning program. The main goals of this article are: (1) to present the foundations of the use of game-based learning in the competence development of engineering students, (2) to describe the main components and functionalities of Edutrivias, and (3) to present the results of an exploratory case study of Edutrivias with information of Chilean students of an engineering school at the University of Talca.

Keywords: Game-based Learning in Engineering, Gamification in Engineering Careers

1 Introduction

Nowadays, one of the factors that has most affected the teaching-learning process is the massive use of technological elements such as smartphones, social networks and online courses, among others. The popularity of these technologies has generated that tradi-

tional methods of teaching fail to attract the interest of the students, losing their applicability and effectiveness [1]. Many universities are no strangers to this phenomenon and try to implement strategies to correct learning problems in courses associated with the basic sciences related to Mathematics, Physics, and Chemistry [2]. These problems are usually associated with a low level of understanding, knowledge, retention, reflection, and application of theory in real cases [3], [4]. In response to the above problems, many academics and researchers are developing teaching-learning methodologies, trying to take advantage of information technologies and virtual environments [5] [6]. An important example of that is the use of online education systems (e-learning) which allow to improve the traditional and formal educational systems. An e-learning system grants flexibility, permanence and synchrony [7]. Other relevant resources are the educational technologies and tools for formal and non-formal learning processes like educational applications in the form of simulators or educational games. The use of games as a learning tool has been extensively studied in the literature, and it has been confirmed that education games are an effective and attractive way to improve the learning process in the students [8].

2 Game-based learning in Engineering Education

2.1 Game-based learning

A general definition presents Game-based learning as a type of game play with defined learning outcomes [9]. In cognition psychology, the role of play as a key factor for cognitive development, don't have discussion. For instance, Piaget describes the role of play for the cognition development of children (from concrete to abstract stages); and for Vygotsky, play is a "leading factor" in children's development and responsible to create a zone of proximal development for the child [10].

Plass et al. presented a number of arguments for the use of game-based learning [10]:

- Motivation. A game motivates learners to stay engaged over long periods through a series of features that are of a motivational nature.
- Player Engagement. Games allow for a wide range of ways to engage learners (cognitive, affective, behavioral and sociocultural engagement). The goal of all these types of engagement, however, is to foster cognitive engagement of the learner with the learning mechanic.
- Adaptivity. Adaptivity is the capability of the game to engage each learner in a way that reflects his or her specific situation. This can be related to the learners' current level of knowledge, to cognitive abilities, to the learners' emotions, or to a range of other variables.
- Graceful Failure. The lowered consequences of failure in games encourage risk taking, trying new things, and exploration. They also provide opportunities for self-regulated learning during play, where the player executes strategies of goal setting, monitoring of goal achievement, and assessment of the effectiveness of the strategies used to achieve the intended goal.

In addition, Prensky describes twelve arguments for the use of games in the learning process. All this argument are in close relationship with the characteristics and goals of the (digital) game-based learning (see Table 1) [11]:

Table 1. Arguments for the use of games-based learning.

Arguments for games	Effects for learning process
1. Games are a form of fun.	Enjoyment and pleasure
2. Games are a form of play.	Intense and passionate involvement
3. Games have rules.	Structure
4. Games have goals.	Motivation
5. Games are interactive.	"Doing" or activity
6. Games are adaptive.	Flexibility
7. Games have outcomes and feedback.	Learning's evidences
8. Games have won states.	Gratification
9. Games have conflict/competition/ challenge/opposition.	Resilience
10. Games have problem solving.	Creativity
11. Games have interaction.	Social interaction
12. Games have representation and story.	Emotional engagement

In a simple description (see Figure 1), the educational games have: (i) an input phase with instructional content and determined game characteristics; (ii) a process phase in form of a game cycle (the players interacted with tasks, the different characteristics and the mechanic of the game, and receive systems feedback); and (iii) the output phase with the results of the interaction [12].

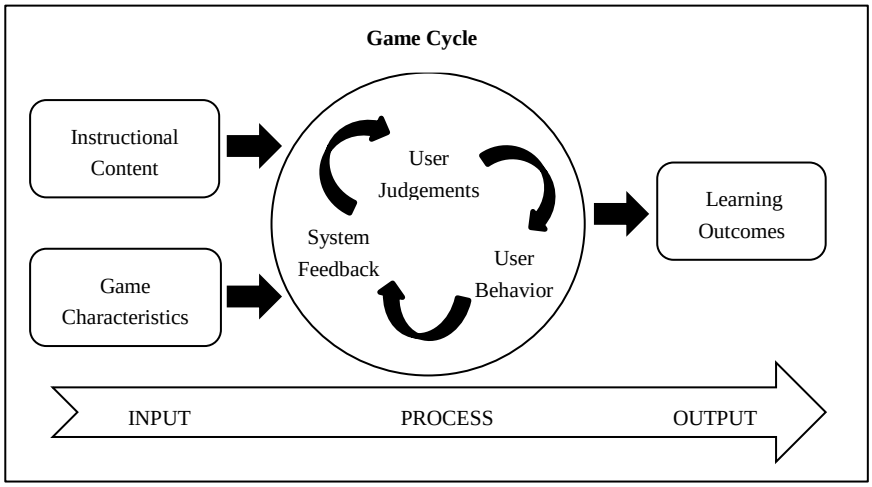

Fig. 1. Input-Process-Output Game Model [12]

2.2 Game-based learning in Engineering

The use of game-based-learning in many engineering fields has been investigated by different authors. The specialized literature on Engineering Education presents experiences at mechanical engineering [13], software engineering [14], and electrical engineering [15] among others. Specifically, for civil engineering, Hartmann et al. (2019) presents research's results about the motivational effects of games at engineering's training process. With the results at the use of seven software tools for civil engineering (GasSolution/T-Xchange, RiskSwitch/T-Xchange, RAMSes, HighwayStakes/ TXchange, among others), the authors concluded that different motivational forms can co-exist when engineering students play the educational games: self-determined motivational forms (intrinsic motivation and identified regulation) and non-self-determined motivational forms (external regulation and motivation) [16].

Although engineering education in many countries is strongly oriented to a traditional lecture-based form (probably for the specific contents related to the knowledge areas and the development of technical skills), the recent literature shows different proposals with the use of education games [16]. Among the effects and contributions of game-based learning to engineering education are: (i) the cognitive growth and digital literacy; (ii) the social-emotional growth; (iii) the soft skills development; (iv) enhanced decision making and problem-solving skills, as well as critical thinking; (v) improvement of the collaboration with others; (vi) generation of a positively competitive environment; (vii) the build of a progressive learning through experience; and (viii) facilitation of feedback driven and student-centered learning [17][18][19].

3 Edutrivias

In this section we describe Edutrivias, a software application that follows the game-based learning paradigm. Edutrivias uses trivia games to support the teaching-learning process. We present the trivia game as a training tool for learning, and its implementation in a digital environment like the Web.

3.1 Trivia games

A "trivia" is a set of questions, where each question has three possible answers, satisfying that just one answer is the right one, and the rest two are wrong. In a "trivia game", the player wins when the number of correct answers is greater than a threshold. Such threshold can be combined with other parameters (e.g. time) to create complex trivia games with one or more participants.

The trivias have been used, for many years, as an evaluation tool. In contrast, we propose to use the trivia as a training instrument. Our hypothesis is that a repetitive training process, based on playing a trivia, will improve the knowledge of the student. In this sense, the students will be able to play the trivia multiple times, i.e. the game has many matches. Each time a student plays a trivia, he/she is acquiring new information

or reinforcing the knowledge acquired in a previous game. In simple words, the student will learn by repetition.

The training process described above enables an important feature: instant feedback. Each time the student finishes a match, he/she can receive specific (for the match) and general (for the game) information about the training process. This information is also valuable for the teacher to be aware about the activity of the student, and his/her level of training. Moreover, the teacher can analyze the performance of the student, and provide additional feedback. A teaching-learning process based on trivias could be tedious and costly to implement in a real environment (classroom), because it implies to create the same material multiple times (i.e. printed trivias). Moreover, the revision and feedback activities imply a lot of time and effort for the teacher. In contrast, a trivia game is feasible to implement as a software application working in a virtual environment like the Web.

3.2 The teaching-learning process in Edutrivias

Edutrivias (http://edutrivias.cl) is a Web application designed to support the teaching-learning process by using the notion of trivia as the central resource. In general terms, Edutrivias considers the participation of teachers and students, whose interaction consists in a group of students playing a trivia created by a teacher. A complete description of the teaching-learning process is presented next.

Assume that the teacher and the students are registered in the system. The process begins when the teacher creates a “Group”, and associates each student with the group (once a time). Additionally, the teacher can generate a group-code and send it to the students, so each student is able to relate itself with the group by using such code.

After the creation of the group, the teacher creates the trivia, that is, a set of questions. Each question is composed of a statement (or question declaration), a picture (which is an optional resource), and three possible answers, such that one answer should be correct, and the other two should be wrong. In order to facilitate the creation of the trivia, the teacher is able to “copy” an existing trivia and take it as the starting point.

Once the trivia is created, the teacher must link the trivia with the group of students. This connection is called a “game”. A game has a “start date-time” and a “finish date-time”, parameters that define a period of time during which the students are able to play the trivia as many times as they want. Based on this, the status of a game could be “created”, “open” or “closed”. Once the trivia is “open” for the students, they are able to play matches. A “match” refers to a (random) subset M of the complete set of questions that compose the trivia. Hence, the students must play multiple matches to review all the questions of the trivia. The size of M must be defined by the teacher during the creation of the game. Additionally, the teacher could define a “timer” that defines a waiting time to get the answer of a query.

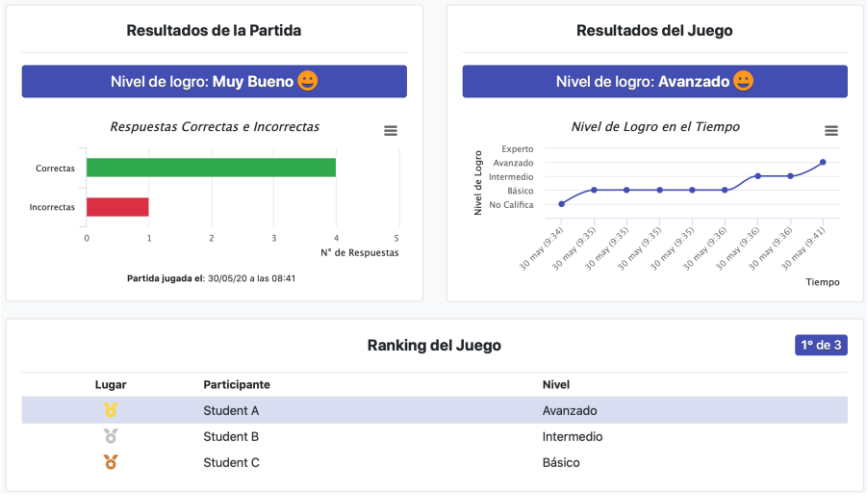

Fig. 2. Report shown to the student after completing a trivia match in Edutrivias.

Each time a student plays and finishes a match, the system presents a report like the one presented Figure 2. The box in the top-left side shows the score for the match, the number of correct answers, and the number of wrong answers. Internally, the system maintains a cumulative score for each question of the trivia. The score of the match is given by the number of correct answers. The box in the top-right side shows the training level of the student in the game, which is given by the cumulative score of all the questions in the trivia. There are five training levels: unqualified (No califica), basic (Básico), intermediate (intermedio), advanced (avanzado) and expert (experto). The box in the bottom shows the ranking of the student in the game. The ranking considers the training level, the number of matches, and the time of participation of the student.

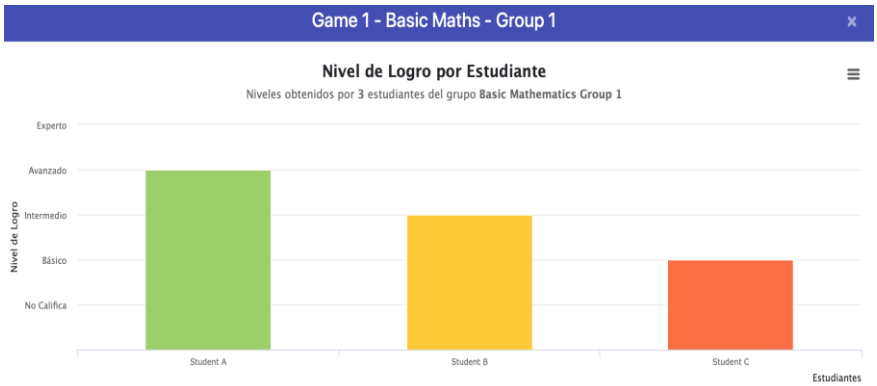

Fig. 3. Report that shows (to the teacher) the training level obtained by the students in a group.

Anytime, during the life of a game, the professor can monitor the activity and evolution of the students, either individually or as a group. For example, Figure 3 shows the report of the training level obtained by each student in a group. Additionally, there is a report that shows the percentage of correct and wrong answers for the whole group of students. This report provides an insight of the concepts that require less or more training.

4 Exploratory case study

Several theories on case study as a research instrument have appeared in the literature [20]. Yin defines a case study as an empirical method of analysis of "a contemporary phenomenon within its real life context" [21] taking into account multiple information sources (e.g., qualitative and quantitative data combination). Yin distinguishes four types of case study designs: single case, multiple case, embedded, and holistic. We conducted an exploratory single-case study where we evaluated the improvement of the teaching-learning process using Edutrivias.

The research questions addressed in this research are the following:

RQ1: What is the interest of the students to use Edutrivias?

RQ2: What is the impact on student scores using Edutrivias?

4.1 Subjects selection

The exploratory case study was carried out during the academic year 2019 with undergraduate students at University of Talca. Specifically, Edutrivias was used in the Database Design module. This module is taken by the students in the fifth semester of the career of Computer Science Engineering at University of Talca. The module is evaluated with two theoretical/practical tests according to teaching units. Edutrivias was used for students as one of study methodology in complement to traditional techniques.

4.2 Evaluation characteristics

The goal of this exploratory case study is evaluating the interest and score impact of students using Edutrivias. The use of Edutrivias can be analyzed from different points of view. First, the interest and use that generate on students, through i) number of students using Edutrivias and ii) time spent in using the software. Second, the effect on academic score that generates on students, through: iii) comparison of evaluations vs training level obtained in Edutrivias, and iv) detection of critical areas.
In this sense, we consider the following evaluation criteria: (1) "interest" is measured as the number students and games using Edutrivias, (2) the "score impact" is measured as related to score test and training level in Edutrivias.

4.3 Data Collection

In this exploratory case study, we conduct an experimentation in software engineering as the method for data collection [22]. A single trivia is associated with each unit of the module, thus, Unit 1 Trivia (U1T) has 56 questions and Unit 2 Trivia (U2T) has 42 questions. These trivia games were available for a period defined by the teacher and their use was voluntary.

Table 2 and Table 3 show the collected data that considers 44 students (7 U1T and 37 U2T). Both tables consider student ID (anonymous), number of games, training level (obtained in Edutrivias) and score test (evaluation). Table 2 shows a score test (column 4) with 10 questions where every student has a number of good answers. On the other hand, Table 3 shows a score test with 5 questions (column 4).

Table 2. Data collection U1T

Student ID	Numbers of games	Training level - Edutrivias	Score test - Evaluation (%)
13	21	Advanced	6/10 (60%)
17	27	Advanced	9/10 (90%)
24	12	Basic	4/10 (40%)
31	72	Advanced	10/10 (100%)
33	34	Advanced	8/10 (80%)
36	8	Basic	5/10 (50%)
44	27	Advanced	9/10 (90%)

Table 3. Data collection U2T

Student ID	Numbers of games	Training level - Edutrivias	Score test - Evaluation (%)
1	16	Expert	5/5 (100%)
3	37	Advanced	5/5 (100%)
4	18	Advanced	5/5 (100%)
5	44	Expert	5/5 (100%)
6	105	Expert	5/5 (100%)
7	5	Basic	1/5 (20%)
8	50	Expert	5/5 (100%)
9	6	Basic	2/5 (40%)
10	45	Advanced	4/5 (80%)
11	6	Basic	3/5 (60%)
12	26	Advanced	5/5 (100%)

13	27	Expert	5/5 (100%)
14	49	Expert	5/5 (100%)
15	19	Expert	5/5 (100%)
16	76	Expert	5/5 (100%)
17	28	Expert	5/5 (100%)
18	49	Advanced	3/5 (60%)
19	14	Expert	4/5 (80%)
20	19	Expert	4/5 (80%)
21	20	Expert	5/5 (100%)
22	23	Expert	4/5 (80%)
24	30	Expert	5/5 (100%)
26	11	Intermediated	4/5 (80%)
27	19	Advanced	4/5 (80%)
28	36	Advanced	5/5 (100%)
29	62	Expert	5/5 (100%)
30	24	Expert	4/5 (80%)
31	43	Expert	4/5 (80%)
32	41	Advanced	4/5 (80%)
33	21	Advanced	5/5 (100%)
37	26	Expert	3/5 (60%)
38	9	Basic	3/5 (60%)
40	15	Advanced	5/5 (100%)
41	14	Intermediated	2/5 (40%)
42	13	Intermediated	4/5 (80%)
43	47	Expert	5/5 (100%)
44	26	Expert	5/5 (100%)

4.4 Data Analysis

To answer each of our research questions, we analyze the number of students and matches reported in Edutrivias. Moreover, we analyze the relation between score test and training level.

Number of students and matches using Edutrivias. In U1T, 7 of 44 students used Edutrivias (15.9% of students), generating 201 matches or interactions. In U2T, 37 of 44 students used Edutrivias (84.1% of students), generating 1119 matches or interactions. Our information shows an increment in the number of students. Probably, students increase the use of Edutrivias for various reasons: complexity of Unit 2, academic motivation, interest in Edutrivias, and others. However, we can see that in general the students with best training levels (expert and advanced) in U1T have better performance

(Table 2); the positive results increase the interest of other students in Edutrivias. Moreover, we observed that students recommended the use of Edutrivias.

Score test and training level relation. In U1T, 5 students have intermediate training level, and 2 students have basic training level. In general, the intermediate level has good performance (80% - 100% good answers) in the evaluation test. In U2T, 20 students have expert level, 10 students have advanced level, 3 students have intermediate level, and 4 students have basic level. In general, the expert, advanced and intermediate level have good performance (80% - 100% good answers) in the evaluation test.

Table 3. Relation between score tests and training level (obtained in Edutrivias)

Training level	Score test vs Training level				
Expert	14 students with excellent answers (100%)	5 students with good answers (80%)	1 student with neutral answers (60%)	0 students with fair answers (40%)	0 students with bad answers (40%)
Advanced	6 students with excellent answers (100%)	3 students with good answers (80%)	1 student with neutral answers (60%)	0 students with fair answers (40%)	0 students with bad answers (40%)
Intermediate	0 students with excellent answers (100%)	2 students with good answers (80%)	0 students with neutral answers (60%)	1 student with fair answers (40%)	0 students with bad answers (40%)
Basic	0 students with excellent answers (100%)	0 students with good answers (80%)	2 students with neutral answers (60%)	1 student with fair answers (40%)	1 students with bad answers (40%)

Table 3 shows three behaviors in the relation between score test and training level: “Consistent behavior”, the students with expert, advanced and intermediate levels have excellent/good/neutral performance (4 students of U2T, 28 students of U1T); “Positive behavior”, the students with intermediate and basic level have good excellent/good performance (4 students of U2T), “Negative behavior”, the students with expert and advanced levels have bad or fair performance (1 student of U2T, 2 students of U1T). Moreover, 2 students of U1T and 3 students of U2T with basic and intermediate levels have fair or bad performance (consistent behavior).

Finally, these results indicate that students increase the interest in Edutrivias in terms of the number of students and games (RQ1). The students have a consistent impact on their test score in terms of relation between their score test and training level (RQ2).

5 Conclusions and Future Work.

The use of trivia games provides various benefits that allow the teacher invest more time in active class activities (e.g., problem-based activities) and generate a better discussion (e.g., debates, conversations). On the other hand, students can take advantage of using trivias to applicate and evaluate knowledge in an entertaining way. In addition, the constant practice of a trivia allows students to achieve a better understanding of concepts and provide students with supplementary material or resources. Constant feedback is another characteristic of Edutrivias, allowing teachers and students to know the achievement levels in a trivia game. Hence, students can be aware of their progress, and are constantly motivated to meet learning objectives. At the same time, teachers could monitor students' progress, and deliver additional and personalized feedback.
Although the study's results and the students' comments show positive effects of the use of Edutrivias at the learning process of engineering students, the researchers are agreed about the need of a bigger number of experimentations and a more detailed analysis of the results.

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