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Importance of learning mathematics through SF and Fantasy digital games: a case study for BEng students

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Abstract

This article presents the results of the creation of digital games, based on science fiction and fantasy themes, and their application in the mathematics subjects of Electronic and Aerospace BEng at the Polytechnic University of Valencia. Students' perception of the activities and their affinity with the chosen themes are studied. Data was collected through a questionnaire and voluntary interviews. A very positive perception of the performance of these activities has been obtained, both in terms of results and motivation.

Keywords: Digital games; game-based learning; science-fiction; engineering education; soft skills.

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1. Introduction

Feelings play an essential role in students' psychological well-being, affecting many aspects of their academic life (Moeller et al., 2020; Phan et al., 2019). Positive feelings influence students' attention, concentration, engagement, and persistence in learning activities. They are also positively correlated with academic performance (Moeller et al., 2020), improved educational outcomes (Villacencio & Bernardo, 2013 and 2016), resilience (Tugade & Fredrickson, 2007), and satisfaction (Howell et al., 2011) and well-being (Hasnain et al., 2014). Conversely, emotions can be also negative reducing students' learning ability and academic performance (Moeller et al., 2020; Valiente et al., 2012).

Therefore, fostering an educational environment of positive feelings can become a tool to improve academic performance outcomes and the learning process, or to promote the development of soft skills and resilience in students (Zamora-Polo et al., 2019; Sánchez-Martín et al., 2017).

The creation of these environments is not limited to promoting positive emotions during the educational activity, but extends beyond the classroom and stems from the choice of a methodology that promotes active and flexible student participation. Providing tools that give students a follow-up on the acquisition of competencies or the possibility of correcting deficiencies also helps to create this environment of positive emotions (Baker & Zubela, 2013; Sánchez-Ruiz et al., 2021, Llopis-Albert & Rubio, 2021). In this regard, blended learning (b-learning) methodologies have had significant success (Forcada et al., 2007; Benta et al., 2015; Sánchez-Ruiz et al., 2021, Recatalá, 2016). Although the fact that these methodologies automatically improve emotions is not a proven fact, they do make the learning process more attractive (Cathcart et al., 2014).

There is evidence in the literature that Game-Based Learning (GBL) methodologies promote a favorable positive emotional environment, enhancing active participation in problem-solving (Connolly et al., 2012; Boyle et al., 2016; Hainey et al., 2016; Zamora-Polo et al., 2019; De-Marcos et al., 2014; Sanchez-Martín et al., 2020) and improving the teaching-learning process (Gordillo et al., 2020; Lopez-Pernas et al., 2019; Ang et al., 2020; Hussein et al., 2019). GBL also generates negative emotions (Ninaus et al., 2019), although these negative feelings have been related to better

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learning outcomes (Shute et al., 2015). Furthermore, GBL methodologies have improved success rates, performance and motivation (Connolly et al., 2012; Mellado et al., 2014), and knowledge acquisition. These techniques have also helped develop transversal and specific competencies (Sanchez-Martín et al., 2017). The greater the positive emotional performance, the better academic grades are obtained (Mellado et al., 2014; Huang et al., 2020), and the improved motivation of the STEM student (Martínez-Borreguero et al., 2018). The acquisition of complicated scientific concepts is also improved when introduced through entertaining experiences (Jiménez et al., 2020; Huang et al., 2020).

Within the GBL techniques, there are many alternatives in the literature. However, among the most prominent are the Educational Escape Rooms (EERs), which can be applied in an extensive range of educational contexts and can foster soft skills such as teamwork, leadership, critical thinking, and communication (Gordillo et al., 2020; Alanazi, 2020). EERs are problem-based activities, whose objective is to solve quizzes, trying to escape from a room (Zhang et al., 2017) in a limited time. Escape rooms are based on a theme and a narrative that guides students through the activity (Nicholson, 2016; Fotaris & Mastoras, 2019). An alternative to face-to-face EER is the design of a digital EER (dEER) (Cadieux et al., 2020). These virtual environments increase students' autonomy and creativity. The objective of the creation of the dEERs was to improve student motivation, knowledge and specific and transversal competencies (Nicholson, 2016; Jiménez et al., 2020), within a dynamic discrete-continuous assessment (DCDA) strategy (Sánchez-Ruiz et al., 2021). This combination GBL-DCDA methodology seems to promote the motivation and participation of the students in the dEER. In this paper, dEER or digital games are created to promote mathematical knowledge within a Mathematics course. Some elements are changed from the usual dEERs or eliminated, so we will refer to them as digital games.

On the other hand, the use of Science Fiction (SF) is becoming popular in the last decades (Orthia, 2015). Scientific questions can be addressed in SF activities so students can attain “the building blocks of scientific literacy” (Czerneda, 2006), and to teach social elements of science and technology. SF provides an excellent educational resource to represent science within a human context (Orthia, 2015) and enhance imagination, creativity, and critical analysis skills (Vrasidas et

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al., 2015; Putt, 2011). Applying SF in science classes can be done by using movies (Bixler, 2007) or stories (Reis, 2004), and novels.

Fantasy topics can also be used in education to engage students and improve the learning process. This can be done is by incorporating fantasy elements into curriculum materials or by the use of role-playing games (RPGs) in the classroom. RPGs are games in which players select the roles of characters in a fantasy world and interact with each other to complete tasks and solve problems. These games can be used to teach a variety of subjects, such as history, language arts, or as stated in this paper, in M subjects. Fantasy literature and role-playing games also allow students to explore complex emotions and can be a tool to develop critical-thinking, problem-solving, and creativity.

This article focuses on the affinity of the students with SF and Fantasy topics, the emotional consequences of applying digital games in the subjects of Mathematics I of the Aerospace and Electronic BEng, have had on the students who have participated in them.

2. Materials and Methods

2.1. Digital Games

Fifteen digital games have been created to be introduced during the classes or to be completed out-of-class in a flip-teaching methodology. Seven were created with the Genially platform (Genial.ly platform, 2023), and six with the RPG Maker MZ software (RPG Maker MZ, 2023). The games are structured so that the tests applied to advance in the game are based on mathematical problems corresponding to the Mathematics subject of the Electronic Engineering BEng and the Aerospace Engineering BEng. The structure of the games created in Genially is based on an escape room scheme, in which students find themselves in a digital room with clues and tests that students must solve to pass to the next room. Digital games created with RPG Maker software follow a similar structure. However, instead of “rooms”, scenarios and interactions with other non-player characters are created. Overcoming these challenges allows players to level up and move on to new scenarios. In these types of games, more importance is given to rewards and role-playing elements, such as leveling the avatar, choosing the character, and providing items. In both cases, themes based on

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science fiction or fantasy have been used to study the affinity of STEM students with these types of genres.

Digital games were aimed to reinforce students' mathematical knowledge and also to introduce new related topics and ideas. Also, they are intended to help develop soft skills, so some of them were designed to be played in groups of four students. In these games, each character chooses different paths which different challenges, providing each of them a part of a final code.

The design of the digital games is based on overcoming various rooms/levels. Students must pass different tests at each level that open the door/access to the next level. In the new level, proceed in the same way. So, until the last level. Each player solves a problem in the room parallel to their peers when the game is collaborative. In this last type, time is a more limiting factor than in the others. A scheme of the process can be seen in Fig. 1. Some screens of a game designed with RPG Maker software can be seen in Fig. 2. The storytelling and the themes applied ranged from SF classics such as 2001 (Arthur C. Clarke), The Martian and Artemis (Andy Wier) or DUNE (Frank Herbert). Fantasy games stem form RPG, in which fantastic items are gained through the completion of quizzes. In these games, enemies are challenged and pose a threat to the avatar of the student.

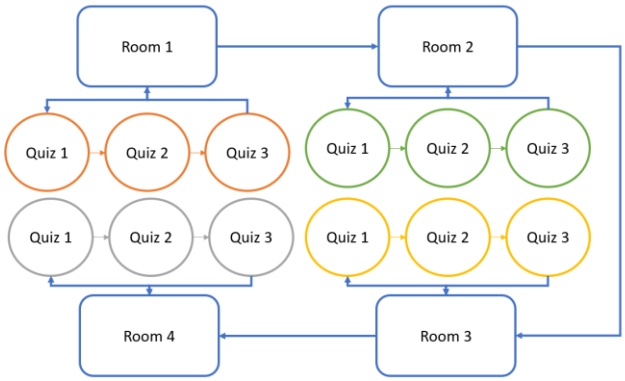

Figure 1. Flow-chart scheme of the digital games

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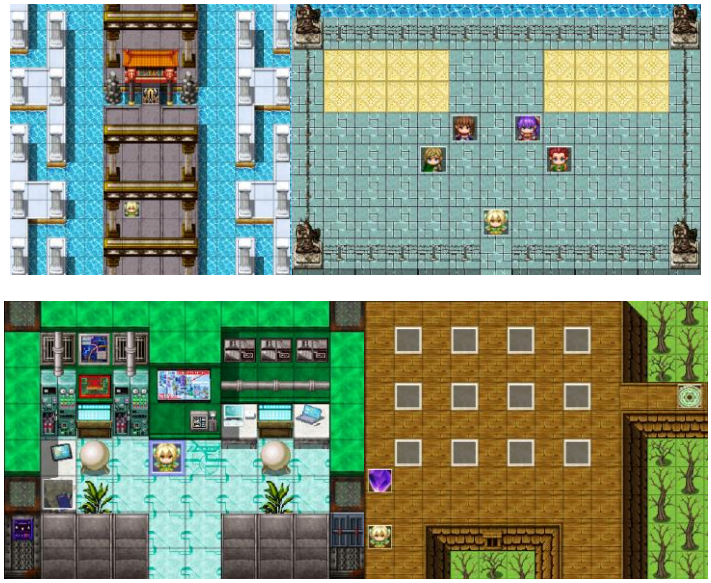

Figure 2. Screen captures of RPG Maker games

2.2. Questionnaire

A 20-question questionnaire was created ad hoc for data collection. The validity of the questionnaire was reviewed by subject area experts. Cronbach's alpha was 0.87. Twenty students agreed to participate in 15-question interviews to collect data about their feelings when participating in the digital games. Notes were taken during the interviews, and sentences were transcribed directly.

2.3. Sample

A total of 78 students finished the questionnaire (69.2% male students and 30.8% female students) and 20 participated in the interviews during the academic years 2020/2021. Students participating in the activities belonged to first-year Electronic Engineering BEng and the Aerospace Engineering BEng. The data was collected after finishing each digital game. Questionnaires were optional and were completed anonymously through the educational platform PoliformaT (Sakai).

2.4. Data Analysis

Data analysis was carried out with SPSS software (IBM) and Excel software (Microsoft). Normality tests, such as Shapiro–Wilk and Kolmogorov–Smirnov, were applied to study the data,

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proving that Likert questions were not normally distributed. In order to compare distributions, non-parametric methods were employed.

3. Results

One of the questions asked the respondents to name what feeling they felt while playing the digital games. Among the most mentioned feelings motivation (39.7%), joy (19.2%), excitement (12.8%), and stress (9.0%). The list of feelings mentioned by the students, their frequency and percentage can be seen in Table 1. It is worth mentioning the high percentage of motivation among the students, and that seven out of nine feelings were positive. However, in the third position, stress appears. In this regard, students have commented that the limited time in the activity and some difficult questions have turned the experience into an emotionally negative activity. Even so, when asked in the interviews, they have mentioned that this type of activity provides more fun and motivation than traditional ones. For example, a student stated that:

"I felt a bit overwhelmed because the time was very short from my point of view. I would have preferred a little more time. I had a great time but the experience was not entirely satisfactory."

Another student mentioned this limitation on the time as frustrating:

"I thought that I didn't have time to answer and that the game would be over, which caused me a bit of frustration. However, in the end we did it and the feeling was wonderful. "

Table 1 Feelings experienced by the students during the digital games.

Feeling	Frequency	Percentage
Motivation	31	39.7%
Joy	15	19.2%
Excitement	10	12.8%
Stress	7	9.0%
Thrill	5	6.4%
Surprise	4	5.1%
Amusement	3	3.8%
Optimism	2	2.6%
Worry	1	1.3%

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The time limitation was considered to increase the commitment to the game. The teachers calculated the time to complete the game, so the students had time to answer the questions. However, the students' perception of this limitation is not homogeneous. There is a positive correlation (p-value < 0.00, Kruskal-Wallis Test) between the positive opinion about the limitation of time and the performance of the students in the subject of Mathematics, that is, the students with better grades evaluate more positively time limitation than lower performing students. Regarding the time limitation, there are no significant differences between male/female answers (p-value = 0.281, Mann–Whitney U test). Nevertheless, there is a significant difference between the students' answers from Electronic BEng and Aerospace BEng (p-value < 0.0.1, Mann–Whitney U test), being the answers of the latter more favorable.

The students were asked about the importance of storytelling in digital games using a Likert scale between 1 and 5, where one means “it is not important at all” and five means “it is very important”. Regarding storytelling, the responses were very positive (Mean = 3.73 , Median = 4, SD = 1.17). In this case, there is no significant difference between the responses of the BEng Engineering and BEng Aerospace students (p-value = 0.925, Mann–Whitney U test) (see Table 2). However, there is a difference between the responses of the male and female students (p-value = 0.03, Mann–Whitney U test). Women valued storytelling more positively (Mean = 4.08, Median = 4, SD = 0.93) than men (Mean = 3.63, Median = 4, SD = 1.23).

Table 2 Importance of storytelling in the digital games

BEng		Statistics	Std. Error
Aerospace	Mean	3.857	0.20144
	Median	4.00	
	Variance	1.420	
	SD	1.191	
	Range	4.00	
	Skweness	-0.704	0.398
	Kurtosis	-0.618	0.778
Electronic	Mean	3.698	0.17462
	Median	4.00	

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Variance	1.311	
SD	1.145	
Range	4.00	
Skweness	-0.563	0.361
Kurtosis	-0.359	0.709

When the students were asked if this type of activity (digital games) improved motivation, the answers of the students varied between 1 "No, it does not improve motivation" and 5 "Yes, it improves motivation a lot". In this case, the results indicated a positive answer in general (Mean = 4.16, Median = 4, SD = 0.75). When we study these responses considering the BEng, there are no significant differences between the answers of Aerospace and Electronic students (p-value = 0.717, Mann–Whitney U test). Also, there is no difference between the responses of the male or female students (p-value = 0.522, Mann–Whitney U test). Some students have mentioned how digital games have increased his/her motivation:

“I have enjoyed played the games. I feel the subject becomes more interesting and attractive when we play games”

“We probably are solving the same exercises as the other groups, but I love to practice exercises with games. They (the exercises) look more fun and interesting. I really feel more motivated with this subject”.

A key factor to apply digital games, apart from increasing positive feelings and motivation, is improving their performance and knowledge of mathematics. In this regard, a question was posed to the students: “do you think digital games have helped you increase your knowledge in mathematics?”. The answers have been very positive (Mean = 3.97, Median = 4, SD = 0.75) and no differences have been found when considering BEng affiliation or gender (p-values < 0.001, Mann–Whitney U test). So, the general feeling of the students seems to be that digital games improve their knowledge.

The students' affinity for digital games was also analyzed. Students were asked how often they play digital games in their leisure time. Responses ranged from 1 "No, I never play" to 5 "Yes, I play whenever I can." There is no significant difference between the answers of the two engineers (p-

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value = 0.438, Mann-Whitney U test), but there is a difference if gender is considered (p-value = 0.004, Mann-Whitey U test). where boys have scored higher (Mean = 4.09, Median = 4, SD = 0.96) than girls (Mean = 3.08, Median = 3, SD = 1.44). When asked if they like digital games, similar results were obtained. In general, the results show that students quite like digital games (Mean = 4.05, Median = 4, SD = 1.03), there is no significant difference between Aerospace and Electronic BEng (p-value = 0.44, Mann-Whitney U test), but there is a significant difference (p-value = 0.0001, Mann-Whitney U test) between male (Mean = 4.44, Median = 5, SD = 0.63) and female (Mean = 3.17, Median = 3, SD = 1.20).

It was studied which genres motivate students the most. When students were surveyed which genres they preferred, the following results were obtained: Science-Fiction (35%), Fantasy (32%), Horror (15%), Crime (9%), Science (8%), and Romance (1%) were obtained. Significantly, the two most mentioned genres are science-fiction and fantasy in engineering. This can be useful to improve the themes of the digital games implemented during the academic year. Science obtained a low score, but was still high enough to appear in digital games. These results can be complemented by their preferences in digital games: action games (35%), simulators (30%), platforms (20%) and strategy (10%), and others (5%).

Finally, we study whether the use of SF and Fantasy themes has improved student motivation. As in the previous cases, a scale from 1 to 5 has been used, where 1 means "No, motivation does not improve at all" and 5 means "Yes, motivation improves a lot". The response to this question has been very positive, as can be seen in Table 3. Next, we have studied whether the factors Gender and Engineering have an influence, and in both cases, no significant differences are observed (p-value SF/Gender = 0.177, SF/BEng = 0.435, Fantasy Games/Gender = 0.876, Fantasy Games/BEng = 0.058, Mann-Whitney U test). Students also claimed to prefer problems based on SF themes (69%), finding these games more align with their interests, rather than fantasy games (31%), which are “fun to play” but more distant from engineering problems.

Table 3 Science-Fiction and Fantasy statistics

Statistics	SF Games	Fantasy Games
Mean	3.79	3.86

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Median	4	4
Mode	5	3
SD	1.23	0.82

4. Discussion

In this case study, it has been obtained that the SF and fantasy digital games implemented in the first-year Mathematics subject for Electronics and Aerospace engineering have been relatively successful in creating a positive learning environment and in increasing their learning. The themes used and the storytelling seems to have significant importance in capturing their interest, although a more in-depth study should be carried out, expanding the number of people surveyed and contrasting with another engineering.

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