D. López-Fernández, A. Gordillo, P. P. Alarcón, and E. Tovar, "Comparing traditional teaching and game-based learning using teacher-authored games on computer science education," *IEEE Transactions on Education*, vol. 64, no. 4, pp. 367–373, 2021.

DOI: 10.1109/TE.2021.3057849
https://doi.org/10.1109/TE.2021.3057849

Comparing Traditional Teaching and Game-Based Learning using Teacher-Authored Games on Computer Science Education

Daniel López-Fernández, Aldo Gordillo, Pedro P. Alarcón and Edmundo Tovar

***Abstract— Contribution*: This article provides evidence on the effectiveness of Game-Based Learning for computer science education when using educational video games created by teachers using authoring tools.**

***Background*: Although teacher-oriented authoring tools for creating educational video games can help overcome the main barriers hampering the use and uptake of Game-Based Learning, there is a lack of studies examining the effectiveness of educational video games authored by teachers using these authoring tools by means of rigorous scientific methods.**

***Research questions*: Is Game-Based Learning using teacher-authored games more effective than traditional teaching in terms of motivation for computer science students? Is Game-Based Learning using teacher-authored games more effective than traditional teaching in terms of knowledge acquisition for computer science students?**

***Methodology*: Two randomized control trials with pre-test, post-test, and one questionnaire were conducted to compare the effectiveness of traditional teaching and Game-Based Learning in two computer science courses. The sample of the two experiments was composed by 75 and 49 students, respectively. Half of the students attended a traditional lecture, while the other half learned solely by playing teacher-authored educational video games.**

***Findings*: The results show that Game-Based Learning using teacher-authored games was practically as effective as traditional teaching in terms of knowledge acquisition, but that it was emphatically successful in increasing student motivation. Students who learned by playing educational video games found the experience more motivating and fun than their counterparts, and a vast majority of them preferred the Game-Based Learning approach over traditional teaching.**

***Index Terms—* Active learning, Educational technology, Games, Computer-based instruction, Computer science.**

I. Introduction

THE academic performance of university students is strongly impacted by their motivation [1]. This is especially important in the field of computer science because computer science degrees usually have high dropout rates [2]. Therefore, computer science education can greatly benefit from new methods capable of increasing student motivation.

A learning methodology that has drawn increasing attention in recent years from educators and researchers due to its potential to increase student motivation is Game-Based Learning (GBL). Within this methodology are framed educational video games, which are explicitly designed with educational purposes. In some games the learning arises from the interaction of the student with the own mechanics of the game, while in other games the learning arises from the student's interaction with embedded learning objects that the game shows when certain events occur.

Several literature reviews published over the last years [3]–[10] show a wide range of studies reporting empirical evidence that playing educational video games can lead to positive impacts in terms of student motivation and learning outcomes. The literature review conducted by Bodnar et al. [6], which focused specifically on the application of GBL in engineering education, concluded that there is a general trend that both student learning and attitudes are improved by using educational games and other game-like activities. However, authors stated that there is need for more outcome data to show the potential effects of GBL in engineering education.

Despite the great potential of educational video games for learning, there are still important barriers hindering their use and adoption, being the most critical of these barriers the low availability of educational video games aligned with the curriculum or that can be easily integrated by teachers into the goals of their courses [11]. One way of overcoming this barrier is the use of teacher-oriented authoring tools capable of allowing any teacher with basic computer skills to easily create and customize their own educational video games. Thereby, teachers will be able to create educational video games tailored to their specific needs and educational settings. Regarding this solution, [3] pointed out an interest in moving away from using

This paragraph of the first footnote will contain the date on which you submitted your paper for review.

This work was supported in part by the *Universidad Politécnica de Madrid* through the educational innovation project "Use of escape rooms and educational video games in higher education" (IE1920.6103) and by the Madrid Regional Government through the e-Madrid-CM Project under Grant S2018/TCS-4307, co-funded by the European Structural Funds (FSE and FEDER)

Daniel López-Fernández, Aldo Gordillo, Pedro P. Alarcón are with the Computer Science Department, *Universidad Politécnica de Madrid*, Madrid, Spain (emails: daniel.lopez@upm.es, a.gordillo@upm.es, pedropablo.alarcon@upm.es).

Edmundo Tovar is with the Computer Languages and Systems and Software Engineering Department, *Universidad Politécnica de Madrid*, Madrid, Spain (emails: edmundo.tovar@upm.es)

COTS (Commercial Off the Shelf) games for learning in favour of designing educational games capable of targeting the desired leaning objectives more precisely.

Although there is no doubt that the use of teacher-oriented authoring tools for creating educational video games is a feasible and outstanding solution, end-user development has received insufficient attention in GBL research [12]. Specifically, there is a lack of studies examining the instructional effectiveness of educational video games created by teachers using authoring tools by means of rigorous scientific methods like RCT (Randomized Control Trials), which is the most rigorous scientific method of hypothesis testing and the best way of determining the effectiveness of novel educational approaches [13]. A proof of this fact is that in the recent literature review on GBL conducted by Boyle et al. [3], in which 143 papers were analysed and classified according to its research design quality, no RCT evaluating the effectiveness for knowledge acquisition of an educational video game created with a teacher-oriented authoring tool was found.

This article presents a comparison of the instructional effectiveness of traditional teaching and GBL using teacher-authored games on two computer science courses by using RCTs. In each RCT, participants were randomly assigned to a traditional lecture or a class where they play educational video games created by the teacher using an authoring tool. The following research questions were explored:

- RQ1: Is GBL using teacher-authored games more effective than traditional teaching in terms of motivation for computer science students?
- RQ2: Is GBL using teacher-authored games more effective than traditional teaching in terms of knowledge acquisition for computer science students?

To the knowledge of the authors, no previous work has conducted a RCT in order to examine the instructional effectiveness of educational video games created through a teacher-oriented authoring tool in a computer science course. A related work can be found in [14], where authors examined secondary students' perceptions toward the use of a set of educational video games created by teachers using an authoring tool by means of a survey. Nevertheless, it should be remarked that no RCT was carried out in this work in order to compare the effectiveness of GBL with alternative teaching methods.

The structure of this article is as follows. Section II describes the research methodology. Sections III and IV present respectively the results of the study and the pertinent discussion. Finally, last section summarizes the conclusions of this research and outlines possible future work.

II. RESEARCH METHODOLOGY

Two separate case studies, described below, were conducted to evaluate the effectiveness in terms of motivation and knowledge acquisition of the GBL approach and the traditional teaching approach in two separate samples. In each of these two case studies, authors conducted a RCT where students were randomly assigned to a traditional classroom lecture (control group) or a class where they play educational video games created by the course teacher using an authoring tool (experimental group). Next sections describe the context and sample of each case study, as well as the methods, instruments and materials used for both of them.

A. Description of case studies

Case Study 1 (hereinafter CS1) was carried out in a database administration course that is part of the bachelor's degree in Technologies for the Information Society from UPM (*Universidad Politécnica de Madrid*), Spain. This course is mandatory, targeted to third-year students, and accounts for 6 ECTS (European Credit Transfer System) credits, equivalent to 150-180 hours of student work. In this case study, the RCT was conducted in a course topic that deals with database security: access and permission control, SQL injection vulnerabilities, legal aspects, etc. The sample of CS1 was composed by 75 students enrolled in the database administration course during the academic years 2019-20 (26 students) and 2020-21 (49 students). They were 65 males and 10 females, and the mean age was 21 with a standard deviation of 1.4. Of these 75 participants, 37 were randomly assigned to the control group and 38 to the experimental group.

Case Study 2 (hereinafter CS2) was carried out in a course on decision support systems that is part of the bachelor's degree in Information Systems from UPM. This course is mandatory, targeted to fourth-year students, and accounts for 6 ECTS credits (150-180 hours of student work). In this case study, the RCT was conducted in a course topic that deals with business intelligence, including configuration and operations with OLAP structures. The sample of CS2 was composed by 49 students enrolled in the decision support systems course during the academic years 2019-20 (27 students) and 2020-21 (22 students). They were 41 males and 8 females, and the mean age was 23.4 with a standard deviation of 2.1. Of these 49 students, 24 were randomly assigned to the control group and 25 to the experimental group.

It should be mentioned that the experiences performed during the 2020-21 academic year replicated the same conditions as those in the 2019-20 academic year (i.e., same courses, same topics, same materials, and same teachers) and there were no repeating students. On the other hand, the realization of each case study involved two teachers each, the usual teacher who were in the control group providing the traditional class and a support teacher who were in the experimental group providing instructions for playing the games. The activities performed by both groups during an academic year were carried out at the same time in different classrooms.

Table I includes the samples of both case studies. It should be noted that the students who participated in both case studies were different, i.e., no student participated in CS1 and CS2.

TABLE I
STUDENT SAMPLE OF THE CASE STUDIES

	CS1	CS2	Total
Control group (Traditional teaching)	37	24	61

Experimental group (Game-Based Learning)	38	25	63
Both groups	75	49	124

B. Methods and instruments

In order to empirically evaluate the effectiveness in terms of motivation and knowledge acquisition of the GBL approach compared to the traditional teaching approach in the two case studies, a RCT with pre-test, post-test, and one questionnaire was conducted in each of them.

First, all students completed the pre-test, which allowed to gauge their prior level of knowledge of the topic covered. Then, the students were randomly divided in two groups: half of them were assigned to the control group and the other half were assigned to the experimental group. Students in the control group attended a traditional classroom lecture while their counterparts in the experimental group attended a class in which they learned exclusively by playing two educational video games. The lectures in both groups had a duration of 1 hour. After that, all students were put together again and performed the post-test, which allowed to effectively measure the knowledge gained after the interventions. Lastly, in order to collect students' opinions on the learning methodologies employed, all of them fulfilled an ad-hoc questionnaire immediately after completing the post-test.

The pre-test and the post-test were composed by the same 10 theoretical multiple-choice questions about the subject to be covered in each case study (CS1: database security; CS2: business intelligence). Students were given 10 minutes for completing each of the tests. No feedback was provided to the students after completing the pre-test to prevent them from memorizing the answers. Nevertheless, correct answers were provided to students after all of them completed the post-test. The pre-test and post-test results did not count towards students' final grades to avoid unexpected behaviours and cheating. The pre-test and post-test were scored from 0 to 10.

The ad-hoc questionnaire included two initial demographic questions (gender and age), a list of six statements with which students needed to agree or disagree using a Likert scale from 1 (total disagree) to 5 (total agree), a yes/no question, and an open question requesting comments. The items of the questionnaire are presented in the next section together the results. The administered questionnaire was the same for all students except for the last two items (items 6 and 7): students in the experimental group were asked if they would have preferred to use traditional materials or to attend a traditional classroom lecture instead of learning by playing educational games, while those in the control group were asked if they would have preferred to learn by playing educational games instead of using traditional materials or attending a traditional lecture.

The content validity of the ad-hoc questionnaire designed to explore the students´ perceptions about the learning methodologies was checked by an expert revision. The consistency and reliability of the survey were also checked using the following statistics: the α of Cronbach, a coefficient to determine the consistency and reliability of the test, was 0.85; and the Kaiser-Meyer-Olkin (KMO) coefficient to determine the sampling adequacy for the test, which was 0.82. These results are considered positive because both α of Cronbach and KMO are between 0.8 and 0.9 (good level) [15], [16].

C. Materials

The only materials used during the traditional classroom lectures (control groups) were typical slides, which were used to support the teacher´s explanation. On the other hand, the students in the experimental group learned exclusively by playing two different educational video games. These games were authored by the course teacher by using the authoring tool provided by the SGAME platform [17], [18], which is publicly available at http://sgame.dit.upm.es. This authoring tool allows teachers without programming knowledge to easily create educational web games by integrating learning objects into existing games. Any learning object compliant with the SCORM e-learning standard [18] can be integrated into a game using the SGAME authoring tool. Thus, teachers can use existing SCORM-compliant learning objects, as well as create their own learning objects from scratch using learning object authoring tools. In the games used for the case studies reported in this article, all learning objects were created by the corresponding course teacher through the ViSH Editor learning object authoring tool [19], which is an online tool available on the SGAME platform.

Educational games created with SGAME are presented to users as conventional entertainment games, but they are interrupted to show learning objects to the players when certain events are triggered. These events may be triggered when certain conditions are met or when the players perform specific actions. When a player successfully consumes a learning object (usually by answering a theoretical question, which commonly is multi-response), the game will reward that player. A traffic light is shown in the windows that display the learning objects to provide feedback to the players. It is always red when a learning object is launched and turns to green when players successfully consume the learning object triggered. The events whose triggering will cause a learning object to be shown to the players, as well as the rewards that players will receive when they successfully consume one of these learning objects are different for each game.

The first type of game used in these case studies is based on a popular 2D mobile game called Flappy Bird. The gameplay is very simple: the player controls a bird who continuously moves to the right between pairs of green pipes, as shown in Fig. 1. Each time the player presses the spacebar key or clicks on the screen the bird briefly flaps upward. If the player takes no action, the bird falls because of gravity. The player scores one point for each pair of pipes successfully crossed, and when the bird touches a pipe a learning object containing a self-graded multiple-choice question is popped up. Fig. 2 shows one of these questions. If the player answers this question correctly, he/she will be able to continue playing. Otherwise, the player will lose and will have to start over again. The goal of the game is to achieve as many points as possible by dodging pipes.

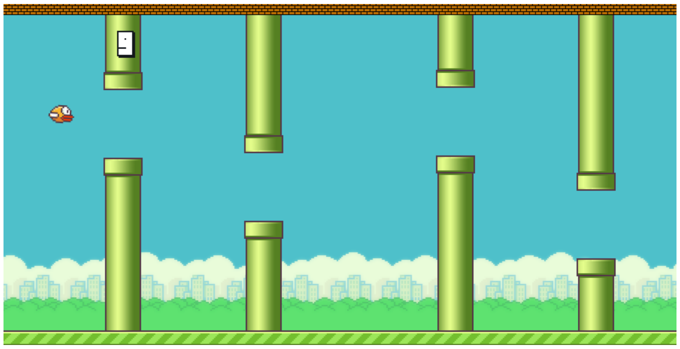

Fig. 1. First type of educational game used by the experimental groups.

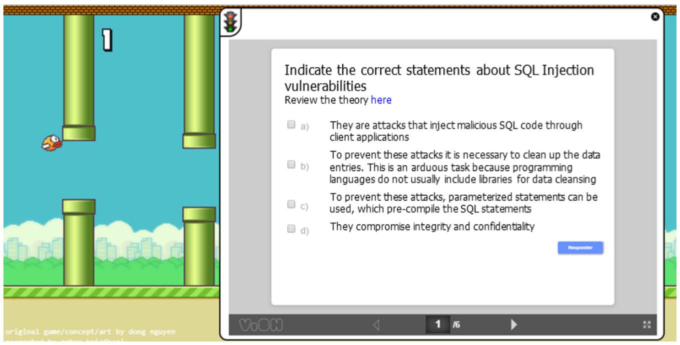

Fig. 2. Multiple choice question integrated in an educational game.

The second type of game used in the case studies is a medieval fantasy shooter game in which the player controls a warrior that has to shoot different kinds of monsters to survive (see Fig. 3). The goal of the game is to kill all the monsters that appear in successive waves. During the game, the players can pick up new items that are helpful or necessary for them to succeed. Each time a player tries to pick up an item, a learning object containing a self-graded multiple-choice question is triggered. The player will only get the new item by successfully answering the question. Otherwise, the item will disappear.

All the learning objects integrated in the games were interactive presentations (created by the teacher with the ViSH Editor authoring tool [19]) with the same structure: the first slide contained a self-graded multiple choice question, and the subsequent slides provided theoretical concepts related to the knowledge assessed by the question included in the first slide. These slides were the same as the ones used in the traditional classroom lecture experienced by the control group. An example of one of these slides is provided in Fig 4.

In each case study, a game of each type was used. Thereby, two educational video games created with SGAME were used in each case study. The games used in both case studies were equal, except for the fact that the learning objects (i.e. the questions and content slides) in CS1 were about database security, while in CS2 the learning objects were about business intelligence. In each case study, the learning objects integrated in each of the two games were exactly the same and students were allowed to choose which game to play.

Fig. 3. Second type of educational game used by the experimental groups.

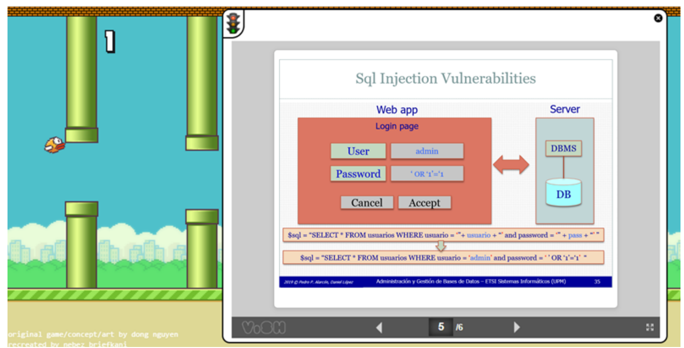

Fig. 4. Learning object integrated in an educational game

D. Data analysis

Paired samples T-tests were conducted to compare the differences between the scores achieved by the participants of each group in the post-test and the pre-test. In order to determine the magnitude of these differences, the Cohen's d effect size [20] was calculated. When using Cohen's d, a value of 0.2 indicates a small effect size; a value of 0.5, a medium one, and a value over 0.8, a large one. Lastly, post-test scores between groups were analyzed using ANCOVA with pre-test scores as co-variate. The results of the questionnaire were analyzed by using descriptive statistics. Furthermore, a series of independent samples T-tests was conducted to determine if there was a significant difference in the ratings between groups. Then, the practical significance of the differences in student ratings was determined by using Cohen's d effect size. Before conducting the statistical tests, normality of the data was checked by means of the Kolmogorov-Smirnov normality test. The results of this test indicated that the data were normally distributed in all cases analyzed.

III. RESULTS

Table II shows the results of the pre-tests and post-tests for the control group and the experimental group of both case studies. For each test, the mean (M) and standard deviation (SD) is shown. No statistically significant differences were found for pre-test scores in either case study when comparing both groups using a T-test for independent samples. On the other hand, statistically significant differences with large effect sizes (Cohen's d ≥ 1.4) between post-test scores and pre-test scores were found in all cases.

In both case studies, the control group slightly outperformed the experimental group in terms of pre-test/post-test score differences. An ANCOVA test showed that these score differences between groups were not statistically significant (p-value > 0.05). By examining the confidence intervals in both case studies, we are 95% confident that traditional teaching does not imply a difference from GBL lesser than -0,4 (-4%) nor greater than 1,0 (10%) in terms of learning gains. Therefore, it can be concluded that neither learning methodology was statistically significantly more effective in regard to knowledge acquisition than the other and that the differences in learning gains between the two learning methods are quite low. It is noteworthy that learning gains were calculated as follows:

$$\frac{(posttest\ score - pretest\ score)}{(10 - pretest\ score)} \quad (1)$$

TABLE II
RESULTS OF THE PRE-TESTS AND POST-TESTS

		Case Study I		Case Study II	
		Control group	Experimental group	Control group	Experimental group
Pre-test	M (SD)	5.2 (1.4)	4.8 (1.1)	2.4 (1.0)	2.6 (1.3)
Post-test	M (SD)	7.4 (1.3)	6.9 (1.2)	7.3 (2.1)	7.1 (2.1)
Cohen's d effect size		1.4	1.4	1.9	1.8

The items of the questionnaire used to examine the students´ perceptions about the learning methodologies are presented in Table III. The results of this questionnaire for CS1 and CS2 are shown in Table IV and Table V, respectively.

In CS1, the mean rating for all items was 3.65 for the control group and 4.4 for the experimental group, while in CS2 the mean rating was 3.8 for the control group and 4.3 for the experimental group. The ratings given by students in the experimental groups were higher than the ratings given by their counterparts, except for one case (item 2 in CS2). In CS1, statistically significant differences with large effect sizes (Cohen's d ≥ 0.8) were found for motivation (item 3), fun (item 4), and preference over the other learning approach (item 6). Moreover, a statistically significant difference with medium effect size (Cohen's d ≥ 0.5) was found for acceptance (item 5). Nonetheless, although overall opinion (item 1) and self-reported learning effectiveness (item 2) were rated higher in the experimental group, these differences were not found to be statistically significant at the 0.05 level. In CS2, statistically significant differences with large effect sizes (Cohen's d ≥ 0.8) were also found for motivation (item 3), fun (item 4), and preference over the other learning approach (item 6). It is worth indicating that self-reported learning effectiveness (item 2) was rated higher in the control group than in the experimental group, although the effect size of this difference was small and non-statistically significant.

When asked about their preference for the two learning methodologies, a majority of students in the control group (60% in CS1, 58% in CS2) stated that they would have preferred to learn by playing educational games, while only a minority of students in the experimental group (9% in CS1 and 17% in CS2) stated that they would have preferred attending a traditional class.

TABLE III
ITEMS OF THE QUESTIONNAIRE

Item	
1	My overall opinion about the learning methodology used is positive.
2	The learning methodology helped me learn.
3	The learning methodology was appealing and motivating.
4	The learning methodology made learning fun.
5	I would like to receive more classes like this one in the future.
Items only included for control groups	
6a	I prefer to learn using traditional materials than playing educational games.
7a	Would you have preferred to learn by playing educational games today instead of attending a traditional classroom lecture?
Items only included for experimental groups	
6b	I prefer to learn playing educational games than using traditional materials.
7b	Would you have preferred to attend a traditional classroom lecture today instead of learning by playing educational games?

TABLE IV
RESULTS OF THE QUESTIONNAIRE FOR CASE STUDY I

Item		Control group	Experimental group	Independent samples T-test p-value	Cohen's d effect size
1	M (SD)	4.2 (0.8)	4.5 (0.7)	0.1	0.3
2	M (SD)	4.2 (0.7)	4.3 (0.7)	0.8	0.0
3	M (SD)	3.7 (1)	4.6 (0.8)	< 0.001	0.9
4	M (SD)	3.3 (1)	4.2 (0.9)	< 0.001	0.8
5	M (SD)	4 (0.9)	4.4 (0.7)	0.05	0.5
6 (6a/6b)	M (SD)	2.5 (1.2)	4.2 (1)	< 0.001	1.4
7 (7a/7b)	Yes (%)	60	9	-	-

TABLE V
RESULTS OF THE QUESTIONNAIRE FOR CASE STUDY II

Item		Control group	Experimental group	Independent samples T-test p-value	Cohen's d effect size
1	M (SD)	4.4 (0.6)	4.6 (0.7)	0.3	0.3
2	M (SD)	4.5 (0.6)	4.3 (0.8)	0.2	0.4
3	M (SD)	3.6 (0.9)	4.5 (0.9)	0.002	1.0
4	M (SD)	3.0 (0.9)	4.4 (0.9)	< 0.001	1.4
5	M (SD)	4.1 (0.7)	4.3 (1.0)	0.4	0.2
6 (6a/6b)	M (SD)	3.1 (1.0)	3.9 (0.9)	0.01	0.8
7 (7a/7b)	Yes (%)	58	17	-	-

The comments gathered from the students were aligned with the presented results. In this regard, it is worth highlighting that some of them pointed out the innovative character of the GBL experience (e.g. "Great class, I appreciate the innovation" or "I found it a different and entertaining class"), as well as others referred to the fun and motivating aspect of the educational video games (e.g. "It is a challenge and motivates you to learn to finish the game. I also love to play games" and "A very gratifying experience, super fun. I love it!") or their utility from a knowledge acquisition perspective (e.g. "I had never known the theory as well as today").

IV. DISCUSSION

The results allow to answer the above-presented research questions. The questionnaire results show that the GBL learning methodology was clearly more effective than traditional teaching in terms of student motivation. Ratings given by students in the experimental groups to the GBL experience in those questions related to motivation and fun were much higher than those given by the students in the control groups to the traditional experience. These results were expected since they are consistent with the current body of scientific research on GBL [3]–[7], which suggest that educational video games are able to positively impact student motivation in many fields, including engineering education. The results of this article provide further evidence on this benefit and prove that educational video games created by teachers using authoring tools, and not solely pre-made educational video games, have the potential of improving motivation of students, which in turn could influence in the choice of their career path. Regarding student acceptance toward the use of teacher-authored educational video games, it should be remarked that an overwhelming majority of students who learned through GBL were satisfied with this approach and did not prefer to learn through traditional teaching methods. In this regard, it is worth pointing out that the reported results are also consistent with those of [14], which found that educational games created with the SGAME platform were perceived by secondary school students as engaging, fun, effective, and preferable to traditional teaching methods.

Regarding instructional effectiveness, the results of the pre-tests and post-tests show that the GBL and the traditional teaching approaches had a similar effectiveness in terms of knowledge acquisition in both case studies. Therefore, the GBL learning methodology was more engaging and motivating than the traditional one and had a similar learning effectiveness. In view of these results, it can be stated that the GBL methodology, although was not more effective in terms of knowledge acquisition than traditional teaching, succeeded to increase student motivation without detriment to learning effectiveness. Thus, these results provide evidence that teachers can easily create motivating and effective educational video games if they are provided with suitable authoring tools. Prior research has reported a wide range of GBL experiences in which pre-made games were found to have more, equal or less learning effectiveness in comparison with traditional teaching approaches [3]–[7]. This work provides evidence on the effectiveness of teacher-authored educational video games, a topic that has received insufficient attention.

Furthermore, given that students following the GBL approach learned autonomously in the reported case studies, the results of this work also suggests that these games have great potential not only for face-to-face learning, but also for self-paced online learning settings, which have recently become particularly relevant due to the COVID-19 crisis.

Finally, despite the positive and promising outcomes of this research, some precautions must be taken. The gathered comments suggest that educational video games are welcomed by the students because they are new and fresh, breaking the routine of the usual classes. However, if GBL would be overused, it would be reasonable to think that the students would probably get bored. Thus, it is important to dose the use of educational video games to maintain its motivational effect.

V. CONCLUSIONS

This article presents two randomized control trials to compare the instructional effectiveness of traditional teaching and Game-Based Learning (GBL) using teacher-authored games in the computer science field. The results show that this GBL approach was very similar to traditional teaching in terms of knowledge acquisition, but that it was emphatically successful in increasing student motivation. Students learning through the GBL approach found the experience more motivating and fun than their counterparts, and a vast majority of them preferred this approach over traditional teaching. Regarding self-reported learning effectiveness, the students perceived both approaches equally beneficial for their learning.

In view of the positive results that can be obtained through teacher-authored educational video games, it would be interesting to carry out more studies like the presented in this paper involving knowledge fields beyond computer science and educational levels beyond higher education.

Regarding the topics that could be addressed, the results of this paper indicate that topics eminently theoretical can be successfully addressed though teacher-authored educational video games. In this way, the precise use of these games would allow to increase the motivation of students and to engage them in a course, which could have a positive impact on their overall academic results. Furthermore, future studies must also explore the usage of these games to promote highly practical skills, whose learning usually involves the usage of approaches like problem solving or case study resolution. Moreover, future studies could also study whether there are gender differences in the use of educational video games.

Lastly, another interesting future work would be to examine the effectiveness of these games in self-paced online learning environments.

REFERENCES

[1] D. Lopez-Fernandez, E. Tovar, P. P. Alarcon, and F. Ortega, "Motivation of Computer Science Engineering Students: Analysis and Recommendations," in *Proceedings of the 2019 Frontiers in Education Conference (FIE 2019)*, 2019, doi: 10.1109/FIE43999.2019.9028635.

[2] I. O. Pappas, M. N. Giannakos, and L. Jaccheri, "Investigating

factors influencing students intention to dropout computer science studies," in *Proceedings of the 2016 ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE '16)*, 2016, pp. 198–203, doi: 10.1145/2899415.2899455.
[3] E. A. Boyle *et al.*, "An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games," *Comput. Educ.*, vol. 94, pp. 178–192, 2016, doi: 10.1016/j.compedu.2015.11.003.
[4] T. M. Connolly, E. A. Boyle, E. MacArthur, T. Hainey, and J. M. Boyle, "A systematic literature review of empirical evidence on computer games and serious games," *Comput. Educ.*, vol. 59, no. 2, pp. 661–686, 2012, doi: 10.1016/j.compedu.2012.03.004.
[5] T. Hainey, T. M. Connolly, E. A. Boyle, A. Wilson, and A. Razak, "A systematic literature review of games-based learning empirical evidence in primary education," *Comput. Educ.*, vol. 102, pp. 202–223, 2016, doi: 10.1016/j.compedu.2016.09.001.
[6] C. A. Bodnar, D. Anastasio, J. A. Enszer, and D. D. Burkey, "Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students," *J. Eng. Educ.*, vol. 105, no. 1, pp. 147–200, 2016, doi: 10.1002/jee.20106.
[7] C. Girard, J. Ecalle, and A. Magnan, "Serious games as new educational tools: How effective are they? A meta-analysis of recent studies," *J. Comput. Assist. Learn.*, vol. 29, no. 3, pp. 207–219, 2013, doi: 10.1111/j.1365-2729.2012.00489.x.
[8] T. E. Coleman and A. G. Money, "Student-centred digital game–based learning: a conceptual framework and survey of the state of the art," *High. Educ.*, vol. 79, no. 3, pp. 415–457, 2020, doi: 10.1007/s10734-019-00417-0.
[9] N. Bado, "Game-based learning pedagogy: a review of the literature," *Interact. Learn. Environ.*, 2019, doi: 10.1080/10494820.2019.1683587.
[10] M. H. Hussein, S. H. Ow, L. S. Cheong, M. K. Thong, and N. Ale Ebrahim, "Effects of Digital Game-Based Learning on Elementary Science Learning: A Systematic Review," *IEEE Access*, vol. 7, pp. 62465–62478, 2019, doi: 10.1109/ACCESS.2019.2916324.
[11] A. Sánchez-Mena and J. Martí-Parreño, "Teachers' acceptance of educational video games: A comprehensive literature review," *J. E-Learning Knowl. Soc.*, vol. 13, no. 2, pp. 47–63, 2017, doi: 10.20368/1971-8829/1319.
[12] Z. Menestrina and A. De Angeli, "End-User Development for Serious Games," in *New Perspectives in End-User Development*, F. Paternò and V. Wulf, Eds. Springer, Cham, 2017, pp. 359–383.
[13] L. M. Woolfson, *Educational psychology, the impact of psychological research on education*. Prentice Hall, 2011.
[14] A. Gordillo, S. López-Pernas, and E. Barra, "Students' perceptions toward the use of teacher-created educational games in a secondary education setting," in *Proceedings of the 12th International Conference of Education, Research and Innovation (ICERI 2019)*, 2019, pp. 1986–1996.
[15] N. Schmitt, "Uses and Abuses of Coefficient Alpha," *Psychol. Assess.*, vol. 8, no. 4, pp. 350–353, 1996, doi: 10.1037/1040-3590.8.4.350.
[16] H. Kaiser and J. Rice, "Little jiffy, mark IV," *Educ. Psychol. Meas.*, vol. 34, pp. 111–117, 1974, doi: 10.1177/001316447403400115.
[17] A. Gordillo, "Contribution to the authoring, distribution, evaluation and integration of learning objects," Universidad Politécnica de Madrid, 2017.
[18] E. Barra, A. Gordillo, D. Gallego, and J. Quemada, "Integration of SCORM packages into web games," in *Proceedings of the 43rd Frontiers in Education Conference (FIE 2013)*, 2013, pp. 685–690, doi: 10.1109/FIE.2013.6684913.
[19] A. Gordillo, E. Barra, and J. Quemada, "An easy to use open source authoring tool to create effective and reusable learning objects," *Comput. Appl. Eng. Educ.*, vol. 25, no. 2, pp. 188–199, 2017, doi: 10.1002/cae.21789.
[20] J. Cohen, "A power primer," *Psychol. Bull.*, vol. 112, no. 1, pp. 155–159, 1992, doi: 10.1037/0033-2909.112.1.155.

DANIEL LÓPEZ-FERNÁNDEZ received the Software Engineer degree and the Ph.D. degree in Software & Systems from the *Universidad Politécnica de Madrid* (UPM). He is currently Assistant Professor with the Computer Science Department, UPM. His main research interests include the application of active learning methods, the development of innovative educational tools and the study of agile methodologies in software companies.

ALDO GORDILLO received the telecommunications engineering degree and the Ph.D. degree in telematics engineering from the *Universidad Politécnica de Madrid* (UPM). He is currently an Assistant Professor with the Computer Science Department, UPM. His research interests include the field of technology-enhanced learning, with a special focus on creation, evaluation, and dissemination of e-learning resources, computer science education, game-based learning, gamification and e-learning systems.

PEDRO P. ALARCÓN received the computer science degree from the Universidad Carlos III de Madrid and the Phd degree in Complex Software Systems from the *Universidad Politécnica de Madrid* (UPM). He is currently a Professor with the Computer Science Department, UPM. He has held several academic positions at the UPM such as Head of Department and Vice-Dean at UPM. He leads the educational innovation group Tutorial Action (GIETA) at UPM. His research interests include data analytics, advanced databases, and the development of innovative educational tools and methodologies.

EDMUNDO TOVAR (M'94–SM'06), received the computer engineering degree and Ph.D. degree in informatics from the *Universidad Politécnica de Madrid* (UPM). He is currently a Professor with the Computer Languages and Systems and Software Engineering Department, UPM. Member of the IEEE Education Society Board of Governors (2005–2012), he is currently President (2021-2022). He leads an Innovation Group in technologies applied to Open Education and he is Editor of the Information Technology / Information Systems Editorial Board of MERLOT. He is professional member of IEEE ETA KAPPA NU.