Comparing the Effectiveness of Video-Based Learning and Game-Based Learning Using Teacher-Authored Video Games for Online Software Engineering Education

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Abstract*—*Contribution: **This article compares the effectiveness for online software engineering education of video-based learning and game-based learning using teacher-authored educational video games created by using authoring tools.**

Background: **Although substantial research has evaluated the impact of video-based and game-based learning versus traditional teaching approaches, little research has been done comparing the effectiveness of video-based learning and video game-based learning. Furthermore, the few studies that performed this comparison did not compare the effectiveness for online education or examined teacher-authored video games.**

Research Questions: **Is game-based learning using teacher-authored video games more effective than video-based learning in terms of knowledge acquisition for software engineering students in online settings? Is game-based learning using teacher-authored video games more effective than video-based learning in terms of motivation for software engineering students in online settings?**

Methodology: **A quasi-experimental design with control and experimental groups and pre- and post-tests was employed. A total of 180 software engineering students participated in this study, 81 of which belonged to the control group while the other 99 were part of the experimental group. The students in the control group took an online lesson in which they learned exclusively by watching videos, whereas the students in the experimental group took the same lesson but learned exclusively by playing an educational video game created by a teacher through an authoring tool.**

Findings: **The results show that game-based learning using teacher-authored educational video games was more effective than video-based learning in terms of both knowledge acquisition and motivation.**

***Index Terms*—Educational games, game-based learning, online education, serious games, software engineering, video-based learning.**

Manuscript received 6 August 2021; revised 2 January 2022; accepted 3 January 2022. Date of publication 25 January 2022; date of current version 28 October 2022. This work was supported in part by the Comunidad de Madrid under Convenio Plurianual with the Universidad Politécnica de Madrid in the actuation line of Programa de Excelencia para el Profesorado Universitario and in part by the European Union and the Comunidad de Madrid through the Project "eMadrid" under Grant S2018/TCS-4307. *(Corresponding author: Edmundo Tovar.)*

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Digital Object Identifier 10.1109/TE.2022.3142688

I. Introduction

ONLINE education has steadily grown worldwide, not only since the outbreak of the COVID-19 pandemic but from its beginning in the 1990s due to the convergence of new technologies, worldwide adoption of the Internet, and intensifying demand for a workforce trained periodically for the ever-evolving digital economy. Moreover, online education is expected to continue growing firmly in the following years and become mainstream by 2025 [1].

An issue frequently mentioned in the literature is the worryingly high dropout rates that courses related to software engineering usually have [2]. This issue becomes even more critical for online software engineering education, since online courses suffer from a large dropout rate of students in comparison with face-to-face courses, especially in science and engineering fields [3]. Therefore, it becomes clear that new learning methodologies and resources capable of increasing the motivation of the students in online settings can be of great help for software engineering education.

A learning methodology that has aroused great interest among teachers and educational researchers over the last few years due to its potential to boost student motivation in both online and face-to-face settings is video game-based learning. As evidenced by multiple literature reviews in the field of game-based learning [4]–[12], this potential has been confirmed by a plethora of studies, which have provided strong empirical evidence, not only that playing educational video games positively impact student motivation but also that it produces positive impacts in terms of learning outcomes. In this regard, it is worth pointing out that game-based learning has been found effective at all levels of education and knowledge areas, including engineering and computing education. Indeed, two of the literature reviews cited above have focused on the application of game-based learning in engineering education [11], [12]. Bodnar *et al.* [11] concluded that there is a general trend that both student learning and attitudes are enhanced by using educational video games, although they stated that more outcome data are needed to show the benefits of game-based learning in engineering education. In turn, Deshpande and Huang [12] concluded that simulation video games (i.e., games designed to closely simulate real world activities) have promising applications in different fields of engineering education.

In addition to the aforementioned literature reviews [4]–[12], which have helped to better understand the impacts and benefits of educational video games, other reviews have been carried out to organize and analyze the current body of knowledge on game-based learning from different angles, addressing issues, such as teachers' perceptions [13], the desirable characteristics of educational video games [14]–[16], the integration of learning content into educational video games [17], and instructional approaches employed to integrate these games into the teaching practice [18].

In video game-based learning experiences, students learn by playing video games, which can be entertainment games that are used with an educational purpose or educational games, i.e., games explicitly designed with an educational purpose. In this regard, it should be remarked that, as pointed out by Boyle *et al.* [4], there is an interest in moving away from using entertainment video games in favor of using educational video games, because these latter games can target learning objectives in a more precise way. The integration of learning elements into educational video games is a very important issue, since the quality of these games depends not only on educational and playful aspects but also on the balance between both of them [16]. This integration can be extrinsic or intrinsic [17]: in educational video games with the extrinsic integration of learning elements, the instructional content being presented has a weak connection with the gameplay; whereas, in those with intrinsic integration, there is an interdependent relationship between this content and gameplay.

Despite the great educational benefits that video game-based learning can bring, its use is not as widespread as it could be. The most critical barrier hampering the use and uptake of this learning methodology seems to be the low number of existing educational video games aligned with the curriculum [13], [19]–[22]. This barrier could be overcome by providing teachers with authoring tools capable of allowing them to easily author educational video games tailored to their particular educational settings and needs. However, despite the large amount of research devoted to game-based learning, little attention has been given to end-user game development [23], [24] and, specifically, to evaluate the impact of educational video games authored by teachers through instructor-oriented authoring tools on student perceptions and performance. Moreover, further research is needed to examine the use of game-based learning in online distance learning settings.

Another learning methodology that has gained substantial attention recently, in this case due to the rise of online education as a result of the COVID-19 pandemic, is video-based learning, which encompasses those forms of learning in which knowledge or skills are taught via video. A wide range of educational benefits of video-based learning have been identified and discussed in the literature, such as allowing students to learn at the time and place of their choosing, facilitating the understanding of the teaching topic, and providing additional processing time for students who cannot fully understand the educational content through traditional lectures and textbooks [25]. Furthermore, this learning methodology is a centerpiece of instructional strategies, such as flipped classroom and blended learning, as well as of online education, since videos are used in practically all online courses.

Substantial research has evaluated the impact of video-based learning versus traditional teaching approaches on student learning (e.g., [26]–[31]), concluding that, in general, video-based learning is at least as equally effective as traditional teaching. Similarly, a large number of studies have compared the effectiveness of video game-based learning with traditional teaching [4]–[12], [32] showing that the former learning methodology is capable of producing higher positive impacts on student motivation and, at the same time, equal or higher positive impacts on student learning. Nevertheless, little research effort has been done to empirically compare the effectiveness of video-based learning and game-based learning using video games. Indeed, only three works addressing this issue have been found in [33]–[35].

Chen *et al.* [33] compared game-based instruction using a simulation video game, video-based instruction, and traditional instruction. The results of that study show that in terms of the acquisition of student scientific knowledge, game-based instruction outperformed video-based instruction, and that both of these learning methodologies outperformed traditional teaching. In [34], students were split into two groups: the experimental group received instruction on computer programming combining the flipped classroom and game-based learning, whereas the control group was taught the same topic using the flipped classroom combined with video-based learning. For conducting the game-based learning experience in the experimental group, a game in the form of a gamified tool for learning coding was used, which was adapted from the game CodeCombat [36]. The results show that students in the experimental group had higher learning performance and motivation than their counterparts in the control group. Another study with a control/experimental group design carried out to compare game-based learning and video-based learning is [35]. In this study, students in the experimental group played a simulation video game and those in the control group watch a video recording of a full demo of said game. The results show that the players outperformed the watchers in terms of language comprehension and vocabulary.

Therefore, the existing evidence suggests that video game-based learning is more effective than video-based learning in terms of both motivation and knowledge acquisition. However, further research is needed for several reasons. First, only three works have provided evidence on this issue [33]–[35] and only one of them has analyzed the difference in terms of student motivation. Second, these works have examined the effectiveness only for three specific knowledge areas: 1) science; 2) computer programming; and 3) language learning. Third, none of these works compared the effectiveness of these learning methodologies for online education, only in face-to-face and blended settings. Finally, it is worth remarking that no work has compared the effectiveness of video-based learning and game-based learning using educational video games authored by teachers through authoring tools.

This article presents a comparison of the effectiveness for online software engineering education of video-based learning and game-based learning using teacher-authored video games (i.e., educational video games that teachers create via authoring tools). Students of a course on software engineering were separated into two groups: students in the control group took an online lesson in which they learned exclusively by watching videos, whereas students in the experimental group took the same online lesson but learned exclusively by playing an educational video game that was created by a course teacher through an authoring tool. The research questions addressed by the study reported in this article are as follows.

1) *RQ1:* Is game-based learning using teacher-authored video games more effective than video-based learning in terms of knowledge acquisition for software engineering students in online settings?
2) *RQ2:* Is game-based learning using teacher-authored video games more effective than video-based learning in terms of motivation for software engineering students in online settings?

To the best of our knowledge, no previous work has addressed these research questions. A related work can be found in [32], where the authors compared the effectiveness of game-based learning using teacher-authored video games and traditional teaching in two face-to-face computer science courses devoted, respectively, to databases and decision support systems. The study reported in the present article continues with this research line by performing a new comparison against video-based learning, the learning methodology most widely used in online education.

The remainder of this article is structured as follows. The research methodology used in the study is detailed in the next section. The results are presented in Section III and discussed in Section IV. Finally, Section V outlines the conclusions drawn from the study and proposes some possible future works.

II. Research Methodology

The study employed a quasi-experimental design with control and experimental groups and pre- and post-tests. Before taking an online lesson on software design principles, the participating students freely chose between two itineraries for this lesson: one based on videos and one based on games. Before making their choice, students only knew that one of the itineraries was video based and the other one was game based. Students were not allowed to change their choice midway through the study. In the video-based itinerary, students learned exclusively by watching short video recordings. Conversely, in the game-based itinerary, no videos were used and students learned exclusively by playing an educational video game, which is described in detail in Section II-D. The control group comprised of all students who chose the video-based itinerary, whereas the experimental group comprised of those students who chose the game-based one.

A. Sample

A total of 180 students participated in this study, 99 of which belonged to the experimental group while the remaining 81 were part of the control group. The experimental group comprised of 86 males (87%) and 13 females (13%) with a median age of 19.9 (SD = 2.1), whereas the control group comprised of 66 males (81%) and 15 females (19%) with a median age of 21.0 (SD = 2.6). All of the participating students were enrolled in a course on software engineering fundamentals taught at Universidad Politécnica de Madrid, specifically at the Faculty of Computer Systems Engineering. This course is mandatory for second-year students pursuing six out of the seven Bachelor's Degrees offered at this faculty. The course is worth 9 European Credit Transfer System (ECTS) credits, which means that it requires 225–270 h of student work. The course provides an introduction to software engineering and covers different topics, including software development processes, software development methodologies, requirements specification, software modeling, software design, and software verification and validation.

B. Procedure

First, a pretest was administered to all participating students in order to assess their knowledge of software design principles prior to taking the online lesson. After that, the students were divided in a control and an experimental group as described above. All students took an online lesson on software design principles, but students in the control group did so watching a set of short video recordings, whereas their counterparts in the experimental group played an educational video game. Specifically, the online lesson was aimed at teaching the SOLID principles (single responsibility, open–closed, Liskov substitution, interface segregation, and dependency inversion), which are among the most well-known and important software design principles. In both groups, the online lesson was designed so that students required around 1 h and a half to complete it. After completing the online lesson, a post-test was administered to all students, allowing thereby to measure the knowledge acquired after the intervention. Finally, once they completed the post-test, all students fulfilled a questionnaire about the learning methodologies and resources employed. The pre- and post-tests, the questionnaire, and all the educational resources used in the intervention were delivered online to the students through the virtual learning environment (provided by a Moodle platform) of the software engineering fundamentals course previously described.

C. Methods and Instruments

The pretest and the post-test were composed by the same set of ten multiple-choice questions and were scored from 0 to 10. These questions assessed the students' knowledge on the SOLID principles and were designed in such a way that, for the students to be able to answer them correctly, they had to not only know and understand these software design principles but also to apply their knowledge to analyze and solve specific software design problems. For both the completion of the pretest and the post-test, students were given 10 min. Although correct answers were provided to the students after the end of the intervention, no feedback was provided to them after completing the pretest in order to prevent them from memorizing the answers. Additionally, students did not know that the post-test had the same questions as the pretest until they took it. Furthermore, in order to prevent cheating and other unexpected behaviors, neither the post-test score nor the pretest score counted toward the final course grade of the participating students.

The questionnaire administered to collect the students' opinions on the learning methodologies and resources involved in the intervention included questions about the age and gender of the respondents, nine statements which required students to specify their level of agreement using a Likert scale with scores ranging from one (Strongly disagree) to five (Strongly agree), and an open-ended question asking for comments. Section III presents the Likert items of the questionnaire together with the results. The administered questionnaire was identical for the two groups with the exception of items 8 and 9: the students in the control group were asked about their opinion on the videos and their preference for video-based learning over game-based learning, whereas those students in the experimental group were asked about their opinion on the educational video game and their preference for game-based instruction over video-based instruction.

The reliability of the student questionnaire was checked by using two statistics: 1) the Cronbach's α [37] and 2) the Kaiser–Meyer–Olkin (KMO) coefficient [38]. The calculated Cronbach's α was 0.84 for the control group and 0.88 for the experimental group, whereas the KMO coefficient was 0.83 for the control group and 0.89 for the experimental group. These results indicate a high reliability of the student questionnaire.

D. Materials

In the control group, the only materials used by the students during the online lesson were a set of six videos: an introductory video plus one video per each of the five SOLID principles. Students in the control group did not take any activity other than watching these videos. All the videos consisted of recordings of slideshow presentations with a voiceover talk. This type of videos is among the ones most used in online courses, especially in those related to engineering and technology [39].

All the videos watched by the students of the control group were recorded by the same course teacher using the OBS Studio tool. In the videos, this teacher explained one by one all the slides of the lesson on SOLID principles. These slides were created with Microsoft PowerPoint. The videos only displayed slides, they did not display the speaker as a small "talking head" placed in a certain area of the frame or any other elements such as embedded quizzes. Therefore, the videos consisted of animated sequences of PowerPoint slides with a voiceover talk.

In the experimental group, students learned exclusively by playing an educational video game and, hence, this game was the only material used by them. This game was authored by a course teacher through the SGAME authoring tool

Fig. 1. Educational video game used by the experimental group.

provided by the SGAME platform [40], which is freely offered to the whole educational community through the following website: http://sgame.dit.upm.es. This authoring tool allows teachers with zero programming knowledge to create customized educational video games very easily by integrating learning objects into premade Web games.

The educational video games the SGAME authoring tool allows to create are Web games that although are presented to the students (i.e., the players) as conventional entertainment games, they are interrupted to show learning objects to the students when certain events are triggered. These events may be triggered when the players perform specific actions or when certain conditions are met. When a player successfully consumes a learning object integrated into a game, the game rewards that player. The windows in which the integrated learning objects are shown to the players include a traffic light for the purpose of providing feedback. When one of these learning objects is launched, the traffic light is red. If the player successfully consumes the learning object triggered, then the traffic light turns green. Thereby, the players know whether they are going to be rewarded once they have finished interacting with a learning object. The rewards that players can receive in the game by successfully consuming learning objects, as well as the game events whose triggering can cause a learning object to be shown to the players are specific of each game. More information on the SGAME authoring tool and the games that can be created with it can be found at [40].

The educational video game examined in this study is a medieval fantasy shooter game in which the player controls a fighter, who is locked in a battle arena and has to shoot different kinds of monsters in order to survive and get gold (see Fig. 1). The objective of the game is to kill all waves of monsters. Naturally, the monsters defend themselves and attack the fighter. Whenever an attack hits the fighter, his health will decrease a certain amount. If at any point the fighter's health reaches 0, he will die and the player will lose the game, so the player will have to start from the beginning again. During the game, the fighter can pick up new items dropped to the

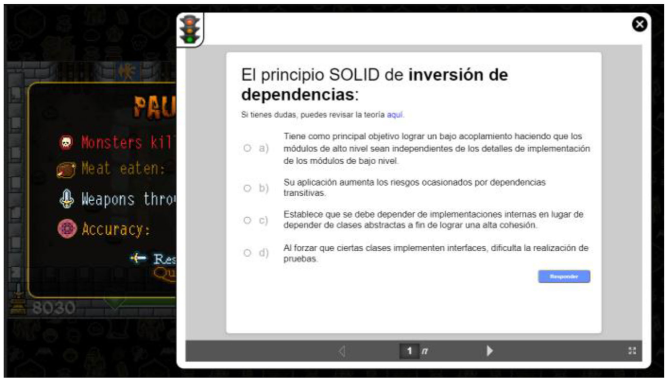

Fig. 2. Multiple choice question integrated into the educational video game.

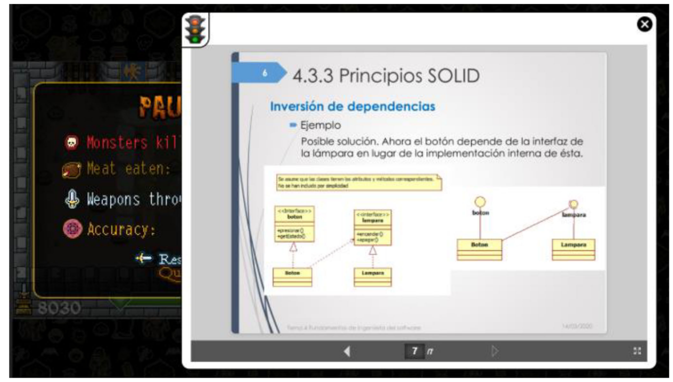

Fig. 3. Slide with theoretical content integrated into the educational video game.

ground of the battle arena by the monsters when killed, which are necessary for the player to succeed.

On the one hand, the fighter can pick up food items, which increase his health making more difficult for the monsters to kill him. On the other hand, the fighter can also pick up new weapons, which allow him to perform more powerful attacks and thereby kill monsters more easily, as well as kill special monsters that could not be defeated with regular weapons. Furthermore, the fighter can collect gold by picking up coins from the ground. Each time the fighter tries to pick up a new item, a learning object containing a self-grading multiple-choice question is popped up (one of these questions is shown in Fig. 2). The fighter will only get the new item if the player successfully answers the question. Otherwise, the item will vanish. Since the fighter will lose health as he fights against the monsters and the weapons have limited ammunition, the player needs to keep picking up new items during the game to be able to win.

If a question is successfully answered, the learning object containing that question will not be shown again to the player. However, if the player answers a question incorrectly, he/she will eventually have another chance to answer it when the fighter tries to acquire a new item. When the player correctly answers all the questions integrated into the game, he/she is notified that the learning objectives of the educational video game had been accomplished and that he/she can stop playing.

All the learning objects integrated into the educational video game examined in this study were interactive Web presentations created by a course teacher through an online learning object authoring tool called ViSH Editor [41] offered by the SGAME platform. All of these learning objects had the same structure: a first part containing a self-grading multiple choice question, and a second part containing theoretical concepts related to the knowledge assessed by the question included in the first part. In some cases, the first part comprised of only one slide containing the question, whereas in other cases, it comprised of two slides, one containing the question and another one containing a UML class diagram related to this question. The second part comprised of 3–7 slides, which provided students with information related to the question. The slides were the same as the ones used in the video recordings. Figs. 2 and 3 show one of the learning objects that was integrated into the educational video game: Fig. 2 shows the slide containing the self-grading question, whereas Fig. 3 shows one of the subsequent slides that provides theoretical content.

TABLE I
RESULTS OF THE PRETEST AND THE POST-TEST

GROUP	PRE-TEST		POST-TEST		LEARNING GAINS		WILCOXON SIGNED-RANKS TEST FOR PAIRED SAMPLES	
	M	SD	M	SD	M	SD	p-value	Effect size (r)
Control (N=81)	3.3	2.1	5.4	2.3	2.1	2.6	< 0.001	0.45
Experimental (N=99)	3.4	1.6	6.3	2.0	2.9	2.4	< 0.001	0.54

E. Data Analysis

The Shapiro–Wilk test of normality was conducted and its results showed that the scores of the pretest, the scores of the post-test, the learning gains (which were calculated as the difference between post-test and pretest scores), and the scores of the questionnaire items were not normally distributed. Therefore, nonparametric statistical methods were used: the Wilcoxon signed-ranks test for paired samples was employed to compare the post-test and pretest scores within each group, whereas the Mann–Whitney U test was carried out for the comparisons between students in the control and experimental groups. The correlation coefficient (r) was used as the effect size measure in all comparisons. According to Cohen's guidelines [42], $0.1 \leq r < 0.3$ represents a small effect size, $0.3 \leq r < 0.5$ represents a medium effect size, and $r \geq 0.5$ represents a large effect size. The results of the student questionnaire were analyzed by using two descriptive statistics: 1) the mean (M) and 2) the standard deviation (SD).

III. RESULTS

A. Knowledge Acquisition

Table I shows the results of the pre- and post-tests for the control and experimental groups. In both groups, the difference between post- and pre-test scores was statistically significant.

TABLE II
ITEMS OF THE QUESTIONNAIRE

Item	
1	My overall opinion on 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 needed help to complete the activities.
6	All the resources were suitably integrated into the platform from which I access them.
7	I would like to learn using the same methodology in the future.
Items only included for the control group	
8a	My overall opinion on the videos is positive.
9a	I prefer to learn using videos than playing educational video games.
Items only included for the experimental group	
8b	My overall opinion on the educational video game is positive.
9b	I prefer to learn playing educational video games than using videos.

TABLE III
RESULTS OF THE QUESTIONNAIRE

Item	Control group		Experimental group		Mann-Whitney U Test	
	M	SD	M	SD	p-value	Effect size (r)
1	4.0	1.0	4.5	0.8	0.003	0.20
2	4.0	1.0	4.1	1.1	0.265	0.05
3	3.6	1.1	4.2	1.0	< 0.001	0.27
4	3.2	1.1	4.2	1.0	< 0.001	0.43
5	2.0	1.4	2.1	1.5	0.790	0.06
6	4.5	0.8	4.3	1.0	0.471	- 0.01
7	4.0	1.0	4.4	0.9	0.006	0.19
8 (a/b)	4.1	1.0	4.3	1.0	0.128	0.08
9 (a/b)	3.6	1.1	4.2	1.0	< 0.001	0.26

In the control group, the effect size of this difference was medium to large ($r = 0.45$), whereas in the experimental group, this effect size was large ($r = 0.54$). These results show that both game-based instruction and video-based instruction were very effective in terms of knowledge acquisition.

No statistically significant difference was found for the pretest scores between groups, confirming that both groups had the same initial level of knowledge of the topic covered by the online lesson. Nevertheless, a statistically significant difference with a small effect size (p-value $= 0.04$, $r = 0.13$) was found in the learning gains between groups. In this regard, it should be taken into account that the learning gains were calculated for each group as the difference between post-test and pretest scores. According to this result, it can be concluded that the learning approach based on teacher-authored video games followed in the experimental group was more effective in terms of knowledge acquisition than the video-based learning approach followed in the control group.

B. Students' Perceptions

Table II lists the questionnaire items that were employed to examine the students' perceptions toward the learning methodologies and resources involved in the intervention, whereas Table III shows the results of this questionnaire for the control and the experimental group, as well as the difference between these groups for each item of the questionnaire.

The average of the scores of all items was 3.7 for the control group and 4.0 for the experimental group. The average ratings given by the students in the experimental group were higher than those given by their counterparts for all items, with the exception of item 6, which is related to the integration of the game and the videos into the course's virtual learning environment. In this regard, it should be noted that the difference for this item was found to be nonstatistically significant with a negligible effect size. A statistically significant difference with a medium effect size was found for item 4 (fun). Moreover, statistically significant differences with small to medium effect sizes were found for items 3 (motivation) and 9 (preference over the other learning methodology). Finally, statistically significant differences with small effect sizes were found for items 1 (overall opinion) and 7 (future use). For items 2 (self-perceive learning effectiveness), 5 (required help), 6 (integration), and 8 (overall opinion on the resources), no statistically significant differences were found.

Overall, the comments made by the students in the questionnaire were aligned with the presented results. In the control group, students remarked the usefulness of the videos to allow them learn at their own pace, praised the quality of the videos and suggest some enhancements. In the experimental group, many students pointed out the innovative character of the activity and thanked the teaching staff of the course for conducting it. Several students also referred to the motivational and fun aspects of the educational video game employed and expressed that they liked this form of game-based learning and that they considered it effective. In the experimental group, few students also suggest supplementing the game with additional resources like videos and slideshows.

IV. DISCUSSION

The results reported in this article suggest that game-based learning using teacher-authored video games is more effective than video-based learning in terms of both knowledge acquisition and motivation for online software engineering education. On the one hand, the learning gains of the students who learned by playing an educational video game were significantly higher than those of their counterparts, who learn by watching video recordings. On the other hand, the ratings given by the students to the game-based learning experience were significantly higher than those given to the video-based one for the items related to motivation, fun, and overall opinion. Furthermore, the students who learn following the game-based learning methodology had a more favorable attitude toward learning using the same methodology in the future. The findings of this article are consistent with those reported by the three previous works [33]–[35] that compared the effectiveness of game-based learning using video games and video-based learning, which also found that game-based instruction outperformed video-based instruction.

An interesting finding of this article is that, although the group that received game-based instruction outperformed the one that received video-based instruction, there was no significant difference in self-perceived learning effectiveness between groups. In other words, although the students who played the educational video game actually learned more than their counterparts, they did not perceive to have learned to a greater extent than the others. This finding reveals a small skepticism on the part of students regarding the instructional effectiveness of video games.

A reasonable question to raise is whether the differences between groups observed in this study are due not only to the learning methodology followed but also to significant differences in the quality of the employed materials. In this regard, it should be noted that the results suggest that both the videos and the game were of good quality because the students who watched the videos had a good overall opinion on these videos and those students who played the educational video game had a good overall opinion on this game. Therefore, it can be stated that the reason why the students who received game-based instruction outperformed those who received video-based instruction was not due to a lack of quality of the employed videos but rather the observed differences were due to the type of learning methodology used.

An encouraging finding for teachers intended to conduct game-based learning experiences in online distance settings is that students did not require more help to play the educational video game than to watch the videos, and that this game was found to be suitably integrated into the course's virtual learning environment. This finding proves that educational video games can be successfully used to conduct game-based learning experiences in online settings, including self-paced online courses such as massive open online courses (MOOCs).

Although the results of this study indicate that students found the conducted game-based learning experience very motivating, it should be taken into account that the ability of this kind of experiences to motivate students has an important limitation. One of the reasons why the students' attitude toward the game-based learning experience was very positive was because this experience was new to them and broke the routine of the course by allowing students to learn by playing an educational video game. Thus, it could be expected that if multiple game-based experiences similar to the one reported in this article were conducted with the same students, the effectiveness of these experiences would eventually decrease because the students would be less motivated due to experiencing a similar gameplay. Bearing this limitation in mind, it is essential for instructors not to overuse educational games in order to conduct effective game-based learning experiences.

Given that these experiences should not be used on a recurring basis during the same academic year with the same students, a reasonable question is when it would be most beneficial to conduct them. Since, generally, the most powerful benefit of game-based learning experiences is enhancing student motivation, an option worth considering would be to conduct these experiences to teach topics that students find particularly uninteresting or conduct them at a time in the academic year when a small boost in student motivation can be especially helpful. Another factor that should be considered before deciding to conduct a game-based learning experience is the suitability of the game to address the desired topic. As evidenced by the reported results, eminently theoretical contents can be successfully addressed by using educational video games like the one described in this study. Nevertheless, promoting highly practical skills in an effective way through games could be more challenging.

The results reported in this article not only provide evidence that game-based learning is more effective than video-based learning in online distance settings but also further evidence of the effectiveness and benefits of both the game-based learning methodology and the video-based learning methodology for online education. Overall, these results are consistent with the current body of research on game-based learning [4]–[12] and video-based learning [25]–[31]. In this regard, it should be pointed out that this article shows that educational video games authored by teachers, and not only premade educational video games, can positively impact student motivation and learning in online settings.

V. Conclusion

In this article, a comparison of the effectiveness of video-based learning and game-based learning using teacher-authored video games for online software engineering education was presented. The results suggest that both methodologies are effective but that the latter is more effective than the former in terms of knowledge acquisition and motivation. The students who learned by playing an educational video game created with a teacher-oriented authoring tool experienced greater learning gains and were more motivated than their counterparts, who learned by watching a set of video recordings. Overall, the results obtained are consistent with those reported by the three previous works [33]–[35] that also compared the effectiveness of video game-based learning and video-based learning.

This article made a novel and significant contribution to the field of education and, specifically, to the field of software engineering education. In this regard, it is worth pointing out that this article provides, for the first time, a comparison of game-based learning using video games and video-based learning in online education. Although previous works [33]–[35] performed this comparison, they did so only in face-to-face and blended settings. Furthermore, neither of these works compared the effectiveness of video-based learning and game-based learning using educational video games authored by teachers through authoring tools. This article evidenced that it is possible to empower teachers to create motivating and effective educational video games for online education by providing them with proper authoring tools. Finally, it is also worth mentioning that only one prior work [34] compared the effectiveness of game-based and video-based instruction for a knowledge area related to computing education. This prior work examined the effectiveness of these methodologies for learning programming, whereas the present article examined this effectiveness for learning software design principles, which is a quite different topic.

Although the study reported in this article provides solid evidence of the effectiveness of game-based learning using teacher-authored video games compared to video-based learning, it is not without limitations. A noteworthy limitation is that the sampling was not random because the participating students freely chose between receive game-based or video-based instruction. Nevertheless, it should be taken into account that the number of participants was similar in the control and the experimental group and that there were no statistically significant differences between groups in terms of initial level of knowledge. The reason why students were allowed to choose the kind of instruction they wanted to receive was to offer all of them the best possible pathway for their learning, since students are often more motivated when they can choose their own pathway. An alternative would have been to force each student to follow a specific itinerary, which would have allowed to employ an experimental design with random assignment instead of a quasi-experimental design. However, this alternative was not selected because allowing students to choose was considered more beneficial for their learning. Another noteworthy limitation of this study is that the reported evidence of the effectiveness of game-based learning and video-based learning is limited to short-term effects. Thus, future works should conduct longitudinal studies in order to examine the long-term learning outcomes of these methodologies.

In view of the positive impacts that game-based learning experiences that use teacher-authored educational video games are able to produce, future works could also examine the use of different game authoring tools and instructional approaches to conduct these experiences in different educational settings. Moreover, future research could compare these experiences with other game-based or gamified learning activities, such as Kahoot quizzes, educational game boards, or educational escape rooms.

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