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SGAME: An Authoring Tool to Easily Create Educational Video Games by Integrating SCORM-Compliant Learning Objects

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ABSTRACT Previous research on game-based learning has provided firm empirical evidence that playing educational video games can positively impact students' motivation and learning outcomes at all levels of education and disciplines. However, the use and uptake of game-based learning in educational settings is being hampered by the lack of authoring tools capable of allowing teachers to easily create educational video games and adapt them according to their needs and contexts of use. Moreover, in order to determine to which extent this kind of tools are useful for teachers to conduct effective game-based learning experiences, further research is required to evaluate these tools from the teachers' perspective, as well as to evaluate the instructional effectiveness of the educational video games that teachers can create by using them. This article contributes to fill this research gap by presenting a teacher-oriented authoring tool for educational games called SGAME, as well as by examining the teachers' perceptions toward this tool and the effect of the educational video games it allows to create on students' perceptions and learning outcomes. A total of three evaluation instruments were used: a questionnaire to collect teachers' perceptions toward the SGAME authoring tool, another questionnaire to collect students' perceptions toward a game created with SGAME, and a pre-test and a post-test to measure the students' learning gains achieved by playing this game. A total of 201 teachers and 79 students participated in the evaluation reported in this article. The results of this article show that SGAME is an easy-to-use authoring tool that allows teachers to create motivating and effective educational video games.

INDEX TERMS Authoring systems, authoring tools, educational technology, educational activities, educational games, game-based learning, serious games.

I. INTRODUCTION

In recent years, game-based learning has drawn increasing attention from instructors and educational researchers due to its potential to increase students' motivation and learning. As evidenced by several recent literature reviews [1]–[8], a wide range of studies have confirmed this potential of game-based learning by providing strong empirical evidence that playing educational video games (i.e., video games explicitly designed with educational purposes) can produce positive impacts in terms of both motivation and learning outcomes. Furthermore, it has been found that

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game-based learning is effective at all levels of education and disciplines [7].

In spite of the great potential of educational video games for providing highly engaging and effective learning experiences, there are still important barriers hampering their use and adoption in educational settings. One of the most critical of these barriers seems to be the low number of existing educational video games aligned with the curriculum or that can be easily integrated by teachers into the goals of their courses [9]–[13]. A proof of this fact is that, in some occasions, in order to conduct game-based learning experiences, teachers resort to use COTS (Commercial Off the Shelf) games designed for entertainment instead of educational video games [1], [14]–[16]. The main problem

of using COTS games for educational purposes is that the learning objectives that can be addressed through them are extremely limited. As a consequence, as pointed out by [1], there is an interest in moving away from using COTS games in favor of designing educational games capable of targeting the desired learning objectives more precisely.

A possible solution for the limited availability of educational video games aligned with the curriculum, as well as to the need to customize these games to adapt them to specific educational settings, is to enable teachers and educational institutions to develop their own educational video games tailored to their specific needs (topics, learning objectives, difficulty, language, etc.). However, developing educational video games is very complex and their cost can be huge [17], which makes such developments inviable for most teachers and educational institutions. A possible way to overcome these barriers is to use authoring tools capable of allowing teachers without programming knowledge to easily create customized educational video games. Nonetheless, there are currently very few authoring tools for creating educational video games available to teachers, and the ones that exist are generally hard to use for users without strong computer skills or have notable limitations in terms of the variety and quality of the games that can be created.

On the one hand, there are several popular game engines and frameworks such as Unity, Unreal Engine, CryEngine, ImpactJS and Phaser, which can be used for developing any type of educational video game [18]. Nevertheless, these authoring systems require users to have solid knowledge of programming and have a steep learning curve, so they are not adequate for most educators. On the other hand, a few teacher-oriented authoring tools have been developed in order to allow educators without programming knowledge to create their own educational video games. Examples of these authoring tools are eAdventure [19] and its successor uAdventure [20], StoryTec [21]–[23], IOLAOS [24], [25] and EMERGO [26]–[28]. A limitation of these tools is that the variety of educational video games that can be created is very small. Indeed, most of them only allow to create games of the story-driven genre. Another limitation of these tools is that the games they allow to create are generally much simpler and limited compared to most entertainment video games, which is an important limitation taking into account that learners expect to find in educational video games the same elements they encounter in the entertainment games they play outside learning environments [29]. Authors of [30] pointed out that existing teacher-oriented authoring tools for educational video games offer few challenges or activities that can be embedded in these games, a complex workflow, and a limited design role for educators. In order to overcome these shortcomings, these authors call for more flexible authoring tools capable of allowing educators to create educational video games. Similarly, [16] concluded that simpler tools for authoring educational video games are needed in order to support wider adoption of these games in educational settings.

In addition to a lack of teacher-oriented authoring tools for educational video games, there is no doubt that end-user development has received insufficient attention in game-based learning research [30], [31]. In this regard, it should be remarked that, in spite of the considerable amount of existing research devoted to educational video games, there is still a lack of studies examining teachers' perceptions toward teacher-oriented authoring tools for educational video games, as well as of studies analyzing the effect of the games created with such tools in students' perceptions and performance.

This article presents SGAME: a web platform that allows teachers to create customized educational video games in a fast and easy way by integrating learning objects compliant with the SCORM e-learning standard into pre-made web games. Moreover, an evaluation of the SGAME platform is also presented in this article, which was conducted to answer the following research question: Is the SGAME platform an authoring tool capable of allowing teachers to easily create effective educational video games in terms of student motivation and learning outcomes? In this evaluation, three factors were examined: the teachers' perceptions toward the platform, the students' perceptions toward the educational games created by teachers using the platform, and the instructional effectiveness of these games. The teachers' perceptions toward the SGAME platform were collected by means of a questionnaire distributed among its registered users. In order to examine the other two factors, a case study was conducted in a computer science course. In this case study, students' perceptions toward an educational game created with the SGAME platform were collected through a questionnaire and the instructional effectiveness of this game was measured by using a pre-test and a post-test.

Previous works have reported game-based learning experiences in which educational games created with the SGAME platform were employed [32], [33], concluding that this type of games can produce positive impacts on both student motivation and learning outcomes. Furthermore, the theoretical model employed by the SGAME platform to integrate SCORM-compliant learning objects into web games has been previously published in [34], [35]. This article presents and reports an evaluation of the SGAME platform for the first time. The objective of this work is to describe the SGAME platform and examine to which extent this authoring tool is useful for teachers to conduct effective game-based learning experiences.

The rest of the article is organized as follows. The next section reviews existing literature on game-based learning, with a focus on teacher-oriented authoring tools for creating educational video games. Section III describes the SGAME platform in detail. Section IV explains how this platform has been evaluated. Section V shows and discusses the results obtained from this evaluation. Lastly, Section VI finishes with the conclusions of the article and an outlook on future work.

II. RELATED WORK

Several literature reviews have been published over the last years in order to summarize and analyze, from different perspectives, the existing body of knowledge in the field of game-based learning. These reviews have contributed to a better understanding of the impacts and outcomes of educational video games [1]–[8], the teachers' perceptions toward these games [9], the instructional approaches that can be used to integrate educational video games into teaching and learning [15], the ways in which learning and content can be integrated into these games [36], and the characteristics of educational video games that may contribute to positively impact game-based learning experiences [37]–[39].

The debate on whether educational video games are positive learning tools seems to have come to an end since a wide range of studies [1]–[8] have provided strong empirical evidence that these games can produce positive impacts in terms of both motivation and learning outcomes at all fields and levels of education. As the instructional effectiveness of an educational video game is influenced by the pedagogical approach used to incorporate it into an educational setting [16], the ways in which game-based learning is applied is a topic that is receiving increasing attention. For instance, [15] examined the instructional activities and approaches that teachers can use in their game-based learning experiences before, during and after gameplay.

The integration of learning elements into an educational game can be intrinsic or extrinsic [36]. In games with intrinsic integration of learning elements, there is an interdependent relationship between gameplay and the instructional content being presented whereas, in those with extrinsic integration of learning elements, this content has a weak connection with gameplay. It has been suggested that educational games with intrinsic learning integration have more potential to produce positive impacts on students' motivation and learning outcomes, however, educational games with extrinsic learning integration have the great advantage of allowing the embedded instructional content to be easily swapped without influencing gameplay [36]. Regarding the integration of learning elements into educational video games, [38] emphasized that quality criteria for educational games should focus on the educational and game aspects, as well as on the balance between them.

Over the last years, several tools aimed at empowering teachers to create their own educational video games have been reported in the literature. One of the most well-known examples is eAdventure [19], a Java-based authoring tool that aimed to allow users without programming knowledge to create "point-and-click" adventure educational games.

The development and maintenance of eAdventure seems to have been abandoned in favor of a new tool termed uAdventure [20]. The uAdventure authoring tool, which has been implemented on top of the Unity game engine, is considered the successor of eAdventure and aims to simplify the creation of "point-and-click" adventure educational games. Although uAdventure can be used by users with zero programming

knowledge, it should be noted that teachers willing to create educational video games with this tool have more than 100 high-level actions available and need to use several editors, which deal with a significant number of variables, settings, and files. Furthermore, some features of the uAdventure tool are intended only for users with expertise in Unity. Although uAdventure undoubtedly constitutes an important contribution to the game-based learning field, as authors of [20] recognized, there is still a need to test the authoring tool in non-assisted environments and verify if the created educational video games can be successfully used in real settings.

Another teacher-oriented authoring tool for creating story-based educational video games is StoryTec [21]. In order to create a game from scratch with this tool, teachers have to create and configure scenes and transitions, add objects, and define actions using a visual programming approach. Two evaluations of the StoryTec tool have been reported: one with 29 students [21], and another one with 26 students [22]. Overall, these evaluations found that students perceived the game authoring tool as easy to use. Moreover, a study involving 47 students was conducted in order to compare StoryTec with eAdventure [22], which concluded that participating students found StoryTec easier to use than the latter authoring tool. In this regard, it should be mentioned that, to the knowledge of the authors, no evaluation has been carried out on the usefulness of StoryTec from the teachers' perspective or on the instructional effectiveness of the created educational games. In another work [23], an extension of the StoryTec authoring tool to allow teachers to integrate content into game templates developed by programmers was presented. However, no evaluation aimed at assessing this extension was reported.

Another authoring tool capable of allowing teachers to create their own story-based educational video games that has been reported in the literature is the one provided by the IOLAOS platform [24], [25]. This tool is based on game templates created by experts, which can be later customized by teachers to adapt them to their specific needs. Although detailed descriptions of the IOLAOS platform and of a game created with it can be found at [24], [25], no evaluation was reported in these works.

Another interesting and relevant software system is the EMERGO platform [26], [27], which allows teachers to create and deliver scenario-based educational video games. To create a game with EMERGO, teachers need to elaborate a game scenario, select and enter educational materials, and define the game script, for which the platform allows them to enter conditions and actions using dialogues that require no programming. The EMERGO platform also enables programmers to provide new components that can be reused in multiple games. A couple of evaluations of the EMERGO platform were conducted involving altogether a total of 9 developed games, 7 teachers and 48 students [26]. The results of these evaluations found that teachers had trouble defining the game scripts when creating the educational video games and that, overall, students were satisfied with the

developed games. Authors of [26] concluded that defining the game scripts through EMERGO turned out to be too difficult for teachers and that it would be probably better to rely on programmers for this task or to provide teachers with predefined game templates. Indeed, in a later work [28], authors stated that actual practice shows that, in EMERGO, game script authoring is mostly too complicated for teachers and even educational technologists and, therefore, it should be done by software developers. In this later work, a software developer and an educational technologist who collaborated to create a game by using EMERGO were interviewed in order to evaluate the usability of the authoring tool. Based on these interviews, it was concluded that the understandability and learnability of the EMERGO game authoring tool are problematic and that its operability is somewhat problematic.

Authors of [13] described how an authoring system called ARLEARN was used to create some educational video games. Although this authoring system allows involving teachers in the development process, technical experts are required to develop the programming code of the games. Therefore, this system cannot be considered a teacher-oriented authoring tool, but a middle ground between these tools and game engines. Another noteworthy related work is that of [40], who presented a model called MoPPLiq and an authoring tool supporting that model called APPLiq, which aims to facilitate teachers to describe scenarios of educational games. A later work [41] reported an evaluation of the APPLiq tool with a small group of teachers, concluding that it can enable educators to design and modify game scenarios.

An authoring tool that has gained increasing popularity recently is Genial.Ly [42], which allows teachers without strong computer skills to create escape room-like educational video games such as the one described in [43]. In spite of its popularity, no evaluation of the usefulness of this tool to create such games has been reported yet. Another system recently released that allows the creation of computer-based educational escape rooms is Escapp [44], a web platform aimed at helping teachers conduct physical and virtual educational escape rooms, both face-to-face and remotely. Although some evaluations of educational escape rooms conducted by using Escapp have been reported in the literature [45]–[47], none of these escape rooms were created exclusively by using Escapp and hence such evaluations do not provide insights on the usefulness of Escapp as a game authoring tool.

In addition to the tools previously described, other tools aimed at enabling educators to create their own educational video games have been reported in the literature such as Edugames4all [48] and its extension Edu-Interact [49], Mokap [50], Game Tel (which is based on eAdventure) [51], and e-Training DS [52]. However, none of these tools have been evaluated and their development seems to have been abandoned after the end of a research project.

Overall, existing literature on game-based learning shows a lack of authoring tools capable of allowing teachers to easily

create educational video games and adapt them according to their needs and contexts of use. Moreover, there is also a need to evaluate these tools from the teachers' perspective, as well as to evaluate the instructional effectiveness of the educational video games created through them. These needs are even more pronounced in the case of authoring tools aimed at creating educational video games of genres other than story-driven, such as platform, shooter, beat 'em up, real-time and turn-based strategy, role-playing, or card-based games. This article contributes to fill these gaps by presenting an easy-to-use educational game authoring tool called SGAME, as well as by examining the teachers' perceptions toward this tool and the effect of the games it allows to create on students' perceptions and learning outcomes.

III. THE SGAME PLATFORM

A. OVERVIEW

SGAME is a web platform that aims to allow teachers to easily create educational video games by integrating learning objects into existing games. SGAME is freely and publicly offered to the educational community via the following web site: <https://sgame.dit.upm.es>. Fig. 1 shows the front page of the SGAME platform. As of 31 March 2021, nearly 1,300 users have registered and created an educational video game on the SGAME platform. As a matter of fact, altogether, these users have created around 3,600 games through SGAME, for which more than 17,500 learning objects have been integrated into them. A user manual for the SGAME platform has been elaborated in order to help teachers learn how to use the platform, as well as to provide them with recommendations to conduct effective game-based learning experiences using educational video games created with the SGAME platform. Furthermore, several video tutorials have also been produced, explaining how to use the main features of the SGAME platform. All these materials are offered through the SGAME website, although it should be mentioned that currently they are only available in Spanish. The software of the SGAME platform has been released under an open source license and it is available at https://github.com/ging/sgame_platform. Thus, it can be

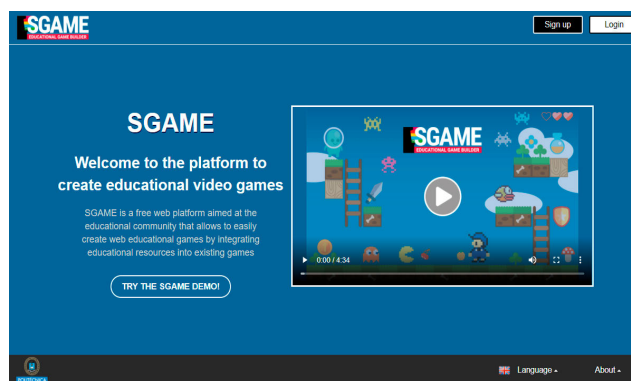


FIGURE 1. Front page of the SGAME platform.

freely used, distributed, studied, adapted, and improved by the research and educational communities.

The SGAME platform provides the following main features to the users: an authoring tool for creating educational video games, an authoring tool for creating learning objects, a learning object manager, and a user profile. Hereafter, we will refer to the authoring tool for creating educational video games as SGAME authoring tool, and to the authoring tool for creating learning objects as ViSH Editor [53], since this tool is an open source authoring tool previously developed that was integrated into the SGAME platform in order to allow teachers to create their own learning objects. Both authoring tools are teacher-oriented, which means that they can be used by users with zero programming knowledge.

The SGAME authoring tool allows teachers to create educational video games by integrating learning objects into existing web games. These existing games, into which learning objects are integrated to create educational video games through the SGAME authoring tool, are termed “game templates”. When creating an educational game using the SGAME authoring tool, any learning object compliant with the SCORM e-learning standard, either with version 1.2 [54] or 2004 [55], can be integrated into the game template. SCORM is the most used content packaging e-learning standard [56] and the one most widely supported in learning management systems and authoring tools. The SCORM standard defines a standardized way to package web-based resources, integrate and launch these resources in learning management systems, and establish communication between these resources and such systems [54], [55]. The next three sections describe, respectively, the characteristics of the educational video games that can be created with the SGAME authoring tool, the specific features offered by this tool, and the technical solution used by the SGAME platform to enable the integration of SCORM-compliant learning objects into the game templates.

The ViSH Editor authoring tool allows users of the SGAME platform to create SCORM-compliant learning objects in the form of slideshows, which can later be integrated into game templates by the teachers through the SGAME authoring tool in order to create educational video games. The learning objects created with ViSH Editor can include a wide range of resources, including text, pictures, videos, audios, different types of self-grading questions, videoquizzes, flashcards, documents, websites, and HTML5 applications. Furthermore, ViSH Editor also allows teachers to convert PDF slideshows created with other tools such as PowerPoint into web-based learning objects and enrich them with additional resources. More details about the ViSH Editor learning object authoring tool can be found at [53]. This prior work also reported an evaluation whose results show that ViSH Editor is capable of allowing educators to create effective and reusable learning objects in an easy way.

The third main feature offered by the SGAME platform to their users is the learning object manager. This feature allows users to upload resources to the platform and manage

their uploaded resources. When a user uploads a SCORM package (i.e., educational content packaged according to the SCORM standard) to the SGAME platform, the learning object manager processes it and makes the packaged content ready to be integrated into a game template. Thereby, users can use learning objects authored from scratch using external authoring tools (e.g., eXeLearning [57] and Educaplay [58]) or retrieved from digital libraries to create educational video games by means of the SGAME platform. In this regard, it is worth pointing out that, even if a resource is not compliant with the SCORM e-learning standard, teachers will still be able to integrate it into a game template by means of the ViSH Editor authoring tool.

All users registered in the SGAME platform have a profile page, which allows them to browse their created games, authored learning objects, and uploaded files. These games, learning objects, and files (including the SCORM packages) can be previewed, downloaded, and shared. The games and learning objects can be exported as SCORM packages, allowing their integration into any virtual learning environment that supports this standard such as Moodle, Sakai and Blackboard.

B. GAMES CREATED WITH THE SGAME PLATFORM

The educational video games created with the SGAME authoring tool are web games that are presented to the players (i.e., the students) as traditional entertainment games, but they are interrupted to show learning objects to the players when certain events are triggered. These events may be triggered when the players perform specific actions (e.g., pick up a new item) or when certain conditions are met (e.g., the player's health reaches zero). When a player successfully consumes a learning object integrated into a game by achieving a certain score or by spending a certain amount of time interacting with it, the game rewards that player (e.g., with a new item or an extra life). If the learning object is not successfully consumed, the player will not obtain the reward. In order to provide feedback to the players, a traffic light is shown in the windows that display the learning objects. This traffic light is always red when a learning object is launched and turns to green when players successfully consume the learning object triggered. Thereby, players are always aware whether they will be rewarded after they have finished interacting with a learning object. The game events whose triggering will cause a learning object to be shown to the players, as well as the rewards that players will receive in the game when they successfully consume one of these learning objects are different for each game template. Moreover, the same game template can define multiple events and rewards. Although not all game templates operate in the same way, the overarching idea is that players will succeed in the games only by consuming and passing the integrated learning objects. A description of a game created with the SGAME platform is provided in Section IV. Furthermore, more examples of games created with SGAME can be found at [32], [33].

Regarding the integrated learning objects, it is worth noting that these learning objects are chosen by the teachers when

creating the educational video games through the SGAME authoring tool. On the one hand, teachers can integrate existing SCORM-compliant learning objects. On the other hand, teachers can integrate learning objects created by themselves using authoring tools, either using the ViSH Editor tool available in the SGAME platform or external authoring tools, as long as the learning objects are compliant with the SCORM e-learning standard. Thereby, teachers can easily integrate practically any type of learning resource, including self-grading questions and videoquizzes, slides, flashcards, etc. Generally, when a self-grading learning object is integrated into a game, players need to pass it (i.e., achieve a certain score) in order to obtain the corresponding reward. For instance, a game could require players to correctly answer a self-grading question to acquire a new weapon that they have found. Although SGAME has been primarily designed with this kind of learning objects in mind, it also allows teachers to integrate non-self-grading learning objects into the games. In these cases, in order to successfully consume the learning object and obtain the reward, instead of passing it, players need to spend a certain amount of time viewing or interacting with the learning object. By integrating an appropriate set of learning objects when creating games through SGAME, teachers can tailor these games to their specific settings and needs.

As previously explained, the integration of instructional content into an educational game can be intrinsic or extrinsic [36]. In the former type of integration there is an interdependent relationship between gameplay and the content being presented, whereas in the latter this content has a weak connection with gameplay, which enables the content to be easily changed. In the games created through the SGAME platform, the integrated content consists of learning objects fully customized by the teachers that relate to gameplay in two different ways. On the one hand, the instructional content is shown to the players only when specific game events are triggered. On the other hand, the interactions of the players with this content are taken into account in order to decide whether players should be rewarded inside the game. In this regard, it should be remarked that, in games created with some game templates, these rewards are mandatory for players to progress, whereas, in other cases, obtaining these rewards is not strictly necessary but extremely helpful to succeed in the game. Therefore, it can be concluded that SGAME supports an integration of instructional content that constitutes a middle ground between intrinsic and extrinsic integration. On the one hand, SGAME allows teachers to easily define and swap the instructional content embedded in the games, which is an advantage of extrinsic integration. However, on the other hand, in the games created with SGAME, there is always an interdependent relationship between gameplay and the instructional content being presented to the players, which is a characteristic of intrinsic integration. Naturally, this relationship is limited by the integration approach employed by SGAME, as well as by the events and rewards defined by the game templates. Generally, the intrinsic learning integration

adopted by educational video games allows for a stronger connection between content and gameplay, but do not allow to easily change the integrated content.

C. SGAME AUTHORIZING TOOL

The interface of the SGAME authoring tool is shown in Fig. 2. In order to better illustrate how this tool allows teachers with zero programming knowledge to create educational video games by integrating learning objects, this section explains all the steps of this process.



FIGURE 2. SGAME authoring tool.

1) CHOOSE THE GAME TEMPLATE

First, teachers must select a game template among all the ones offered by the SGAME platform. The current version of the SGAME platform provides a total of 10 game templates, allowing teachers to create educational video games of different genres, including platform, shooter and role-playing games. In this regard, it should be taken into account that software developers can easily convert existing web entertainment games into game templates that the SGAME authoring tool can use to enable teachers to create educational video games, and thus it is expected that the number of game templates available in the SGAME platform increases in the near future. The next section provides details on how to convert web games into SGAME-compliant game templates. In addition to providing a set of ready-to-use game templates, the SGAME authoring tool allows users to upload new game templates. Nevertheless, this feature is not aimed at teachers, who are not expected to develop game templates, but rather at game developers or users with high programming knowledge.

As explained before, each game template defines its own game events and rewards, which determine how the instructional content and gameplay connect with each other. When teachers select a game template in the SGAME authoring tool, they can consult all its events and rewards, as well as additional information of the game template, including its

description and language. Moreover, teachers can play the game template to get an idea of the game.

2) CHOOSE THE LEARNING OBJECTS THAT WILL BE INTEGRATED INTO THE GAME TEMPLATE

After selecting a game template, teachers must choose the learning objects they want to integrate into it in order to create the desired educational video game. As explained before, teachers can integrate any learning object compliant with the SCORM e-learning standard. On the one hand, they can integrate learning objects authored through the ViSH Editor authoring tool available in the SGAME platform. On the other hand, they can integrate learning objects contained in SCORM packages, which allows the integration of instructional content authored outside the SGAME platform or downloaded from external repositories. In this regard, it is worth mentioning that, when teachers upload SCORM packages, the SGAME authoring tool allows them to select which learning objects of such packages they want to integrate into the game. When performing this step, teachers can also preview and interact with the learning objects.

3) MAPPING BETWEEN LEARNING OBJECTS AND GAME EVENTS

In this step, teachers must associate the events of the game template with the learning objects selected in the previous step. Zero, one, all, or a subset of the selected learning objects can be mapped (i.e., associated) to each of these events. In order to help teachers carry out this mapping, various information on the events is shown, including a description explaining when the event is triggered and which reward is given to the player in case of success, the type of event, and its frequency. Unless some sequencing option prevents it, when a game event that has been mapped with learning objects is triggered, one of such learning objects will be shown to the player. When this happens, the way in which SGAME determines the learning object to be shown depends on the sequencing options specified in the following step. By default, this learning object will be selected randomly among the ones mapped to the game event that have been shown to the player fewer times.

4) SEQUENCING OPTIONS

In this step, teachers can define sequencing options in order to indicate how the game must choose the learning objects to be shown to the players. The current version of the SGAME platform supports three sequencing options. The first option enables to specify whether the game should show the same learning object more than once. Game authors can choose among allowing all learning objects to be shown again, allowing to show again only those learning objects that the player has not successfully consumed, and not allowing to show any learning object more than once. The second sequencing option allows teachers to indicate when can the game be interrupted to show learning objects. By default, the game will show a learning object whenever occurs an event for

which there is a mapped learning object that can be shown. Notwithstanding, teachers can specify a maximum number of interruptions per game session, or a time limit, preventing the game to show more than one learning object in each time slot. The last sequencing option allows teachers to specify a strict order in which learning objects must be presented to the players. If this option is not specified, the learning objects will be shown in random order.

5) GAME SETTINGS

Besides sequencing options, the SGAME authoring tool allows teachers to specify settings for the educational video games that are not related to the sequencing of the integrated learning objects. A total of four game settings are supported in the current version of SGAME. Each of these settings is described in one of the following four paragraphs.

When an educational video game created with SGAME is integrated into a virtual learning environment (e.g., Moodle) as a SCORM package, it reports the following information to it in each game session: time spent, success status (indicates whether the learner has mastered the learning objectives of the game), completion status (indicates whether the learner has completed the learning objectives), score (grade achieved by the learner in the game), and progress measure (measure of the progress the learner has made towards completing the learning objectives). The first game setting allows authors to specify the condition that must be met for the completion status to be reported as 'completed'. This can occur when the player has seen all the learning objects integrated into the game, or a certain percentage or number of them, when the player has seen whatever learning objects a certain number of times (this setting is especially useful for adaptive learning objects capable of changing their behavior according to the learner's actions), when the game starts, or never.

The second game setting allows authors to specify the condition that must be met for the success status to be reported as 'passed'. This setting supports the same conditions as the first setting, but these conditions require the player to successfully consume the learning objects instead of just to see them. Moreover, teachers can specify that the success status change to 'passed' whenever the completion status changes to 'completed'.

The educational video games created with the SGAME platform can notify the player that its learning objectives have been achieved and that the activity has come to an end. This feature aims to help teachers to limit and control the time of the game-based learning experiences conducted using games authored by means of SGAME. The third game setting allows teachers to specify whether and when this notification should be shown. If teachers choose to display the notification, they may decide to display it when the game cannot show any more learning objects, when the player has successfully consumed all learning objects, when the completion status of the game changes to 'completed', or when the success status of the game changes to 'passed'.

It is possible that, when a game event mapped to a set of learning objects is triggered, none of these learning objects can be displayed, e.g., if all of them have been previously shown and the sequencing option that prevents learning objects to be shown more than once is activated. For these cases, there is a fourth game setting that allows teachers to specify how the game must behave. This setting allows to specify if the game should act as if the player had successfully consumed the learning object or not depending on the event type.

6) METADATA

This step is intended to allow teachers to specify metadata for the educational video game they are creating. The current version of the SGAME platform supports the following two metadata fields: title and description. When a game created with SGAME is exported as a SCORM package, these metadata, together with other metadata automatically generated by the platform (e.g., URL, creation date, type of learning resource), are included in the SCORM package according to the IEEE LOM [59] format.

7) GAME CREATION

Before finishing the creation process, teachers can review all the steps they have previously carried out with the SGAME authoring tool. Then, they only need to click on a button to create the educational video game. After that, they will be redirected to a web page in which they will be able to play that game. All games created with SGAME can be shared through a URL, as well as exported as SCORM packages in order to be integrated into SCORM-compliant virtual learning environments. Once a game has been created, teachers can edit it with the SGAME authoring tool at any time. Thereby, they can easily swap the integrated learning objects, as well as modify the mapping, sequencing options, settings, and metadata of the educational video game.

D. INTEGRATION MODEL

This section briefly describes the model employed by the SGAME platform to integrate SCORM-compliant learning objects into web games. Further details about this model, as well as an analysis of the possibilities that the SCORM e-learning standard offers to integrate learning objects into games, can be found at [34], [35].

Before explaining the SGAME integration model, it is important to note some characteristics of the SCORM standard [54], [55]. Each resource contained in a SCORM package can be a SCO (Shareable Content Object) or an asset. A SCO is a resource that will use the SCORM API to communicate with the learning management system, and an asset is a resource that is used in a learning activity but does not use the SCORM API and hence does not communicate with the learning management system. A SCO can report various information to the learning management system using the SCORM API including success status, completion status, score, and progress measure. However, it should be taken into

account that SCORM does not require SCOs to report any data.

Fig. 3 shows the architecture defined by the SGAME model, including the different components involved in the integration of SCORM-compliant learning objects into web games in order to create educational video games and the interactions among these components. In this model, the term “game instance” refers to the educational video games that can be created with SGAME. Game instances are composed of a game template, the SGAME API, and a set of SCORM-compliant learning objects. Therefore, these learning objects can be SCOs or assets. In this regard, it must be mentioned that users of the SGAME platform can indicate, for each of the SCORM packages they upload, if the packaged SCOs report data. The SCOs that do not report any data will be treated as assets by the SGAME platform.

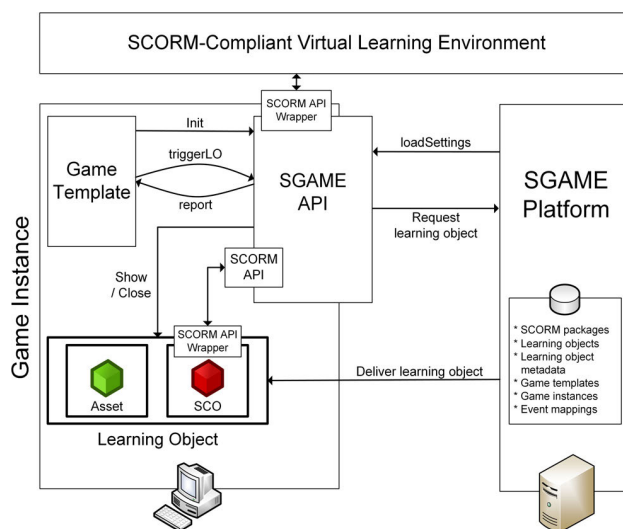


FIGURE 3. SGAME architecture.

The SGAME API is a JavaScript API that allows any web game to request learning objects to the SGAME platform and show them to the players inside the game, as well as to obtain tracking data about the success and progress of the players with these learning objects. In order to obtain the tracking data reported by the SCOs, the SGAME API uses a tailored SCORM API.

Each time a player finishes interacting with a learning object and closes it, the SGAME API reports to the game template all available tracking data (time spent, success status, completion status, score, and progress measure), a true/false value termed “success parameter” indicating whether the player has successfully completed the learning object, and the metadata of the learning object. The success parameter is automatically calculated by the SGAME API in a different manner depending on whether the learning object is an asset or a SCO. Since assets do not use the SCORM API and hence they do not report any tracking data, the only relevant information that can be obtained in these cases is the time the player spent on the asset. Thus, for assets, the success

parameter is calculated based on this time and a reference time automatically calculated according to the typical learning time defined in the metadata of the asset, which can be specified by the teacher who creates the game. For SCOs, the SGAME API calculates the success parameter using the tracking data reported by them. If a SCO does not report enough tracking data to calculate this value, it will be calculated in the same way as for assets. More details about the calculation of the success parameter can be found at [35].

Game templates should use the data reported by the SGAME API each time a player closes a learning object to determine if the player should be rewarded and, if so, to decide which reward should be given. Thereby, players are rewarded when they successfully complete the integrated learning objects. According to the SGAME model, game templates are responsible for defining the specific events whose triggering will cause learning objects to be shown, as well as for determining the rewards that players will receive when they successfully consume these learning objects based on the data reported by the SGAME API.

The SGAME API is also in charge of enabling the integration of the game instances created in the SGAME platform into virtual learning environments compliant with SCORM. For achieving this integration, in each game session, the SGAME API gathers data on the interactions of the player with the different learning objects integrated into the game instance, combines and processes these data according to the game settings specified by the teacher through the SGAME authoring tool, and notifies the tracking data of the game instance to the environment into which this game instance is integrated.

Lastly, it is worth pointing out that the SGAME API has been designed in order to be simple to integrate and use in existing games. Therefore, game developers can use this API to easily convert existing web games into SGAME-compliant game templates. The requirements that game developers should take into account to carry out this conversion are described in [35].

IV. EVALUATION METHODOLOGY

This article explores the following research question: Is the SGAME platform an authoring tool capable of allowing teachers to easily create effective educational video games in terms of student motivation and learning outcomes? In order to answer this question, the following three factors were evaluated: the teachers' perceptions toward the SGAME platform, the students' perceptions toward the educational games created by teachers using this platform, and the instructional effectiveness of these games.

A. TEACHERS' PERCEPTIONS TOWARD THE SGAME PLATFORM

1) SAMPLE

A total of 201 teachers who have created at least one educational video game through the SGAME platform participated

in this evaluation. Of these 201 teachers, 98 (48.8%) were men and 103 (51.2%) were women. Participating teachers were aged between 22 and 70 years, being 38.9 the mean age, 38.0 the median age, and 10.9 the standard deviation. Regarding the level of education, 32 (15.9%) teachers worked in childhood education, 72 (35.8%) in primary education, 71 (35.3%) in secondary education, 54 (26.9%) in higher education, 11 (5.5%) in special-needs education, and 10 (5.0%) were teachers working at non-formal education institutions. In this regard, it should be clarified that several of the teachers worked at multiple educational levels.

When asked about their prior experience with educational technology, 9 (4.5%) of the participating teachers declared to have no experience, 13 (6.5%) declared to have low experience, 37 (18.4%) declared medium experience, 82 (40.8%) declared medium-to-high experience, and the remaining 60 (29.9%) declared high experience. When asked teachers if they thought that game-based learning is very useful for education, a vast majority (83.4%) answered positively, whereas 11.6% neither agreed nor disagreed, and only 5% answered negatively.

2) METHODS AND INSTRUMENTS

In order to collect teachers' perceptions toward the SGAME platform, an online questionnaire was distributed among the users registered in this platform that had created at least one educational video game through the SGAME authoring tool. Although more than 320 answers were collected, only those responses from teachers were considered, resulting in a total of 201 valid responses. In this regard, it is worth noting that responses from student teachers, researchers and technicians were excluded from the sample. The questionnaire was voluntary, anonymous, and no reward was given to those users who completed it.

The questionnaire included some demographic questions, closed-ended questions on overall acceptance and usability of the SGAME platform, a list of statements with which participating teachers needed to agree or disagree using a five-point Likert scale, and an open-ended question asking for additional comments. The items of the questionnaire are presented in the next section along with the results.

The reliability of the questionnaire was checked by using the Cronbach's α [60]. The calculated Cronbach's α was 0.95, indicating an outstanding reliability.

3) DATA ANALYSIS

The results of the questionnaire completed by the teachers were analyzed by using the following descriptive statistics: mean (M), median (MED), and standard deviation (SD). All comparisons between different groups of teachers (e.g., among teachers working in different educational levels) were performed using the Mann-Whitney U test, since the scores of the questionnaire items were not found to be normally distributed when a Shapiro-Wilk test was conducted. The correlation coefficient (r) was used as the effect size measure. According to Cohen's guidelines [61],

$0.1 \leq r < 0.3$ 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.

B. STUDENTS' PERCEPTIONS AND INSTRUCTIONAL EFFECTIVENESS OF THE GAMES CREATED WITH THE SGAME PLATFORM

In order to examine these two factors, a case study was conducted, which examined the use of a game created with the SGAME platform in a higher education setting.

1) SAMPLE

The sample of this case study consisted of 79 students, who were enrolled in a third-year core course on databases that is part of the Bachelor's Degree in Biomedical Engineering from UPM (Universidad Politécnica de Madrid). This course accounts for 6 ECTS (European Credit Transfer System) credits, equivalent to 150-180 hours of student work, and aims to introduce the basics of databases, big data, and SQL and NoSQL databases. Of the 79 students who participated in this case study, 32 (40.5%) were men and 47 (59.5%) were women. These students were aged between 20 and 25 years, being 20.5 the mean age, 20.0 the median age, and 0.8 the standard deviation.

2) METHODS AND INSTRUMENTS

A mandatory learning activity on databases and big data fundamentals was conducted online and asynchronously. This activity was designed to require around one hour and a half for students to complete it. First, students watched a video explaining the instructions of the activity. Then, students completed a pre-test. After that, students played an educational video game created with the SGAME platform, which had integrated a total of 24 learning objects. Each of these learning objects required students to correctly answer a question in order to pass it. The next section provides more details about the employed game, as well as of these learning objects. Once students passed all the learning objects integrated into the game, they were notified that they had accomplished the learning objectives of the game and that they could stop playing. After that, students completed a post-test and, optionally, a questionnaire on the educational video game they have played. In order to collect honest answers, this questionnaire was conducted anonymously.

Thereby, the students' perceptions toward the educational game created with the SGAME platform examined in the case study were collected through a questionnaire and the instructional effectiveness of this game was measured by using a pre-test and a post-test. All students in the sample completed the pre- and post-test, whereas the questionnaire was completed by 71 out of the 79 students.

The student questionnaire included a closed-ended question addressing overall opinion of the game, several statements with which students needed to agree or disagree using a five-point Likert scale, a yes/no question, and an open question requesting comments. The items of the questionnaire are

presented in the next section together with the results. The reliability of this questionnaire was checked by using the Cronbach's α [60]. The calculated Cronbach's α was 0.90, indicating an excellent reliability.

The pre-test and the post-test were composed of the same 10 multiple-choice questions about databases and big data (the topic covered by the game-based learning activity). 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. Thus, the correct answers were not provided to students until after they completed the post-test. Regarding this matter, it is worth indicating that, until students took the post-test, they did not know that it had the same questions as the pre-test. The pre-test and post-test results did not count toward students' final grades in order to avoid unexpected behaviors and cheating. Given that each question was worth one point, the maximum score that a student could achieve in the pre- or post-test was 10, while the minimum score was 0.

3) MATERIALS

The game-based learning activity previously described was delivered online by using the Moodle platform of the course. All materials (the video, the tests, the educational video game, and the student questionnaire) were provided via Moodle. In this regard, it is worth indicating that the game was exported as a SCORM package from the SGAME platform in order to integrate it into Moodle using this standard. The educational video game examined in this case study was created with the SGAME platform by using a game template based on the popular 2D mobile game Flappy Bird. The gameplay is very simple: the player controls a bird that moves continuously to the right between pairs of green pipes, as shown in Fig. 4. Each time the player clicks on the screen or presses the spacebar 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 passed, and when the bird touches a pipe a learning object containing a self-grading question is popped up. If the player answers this

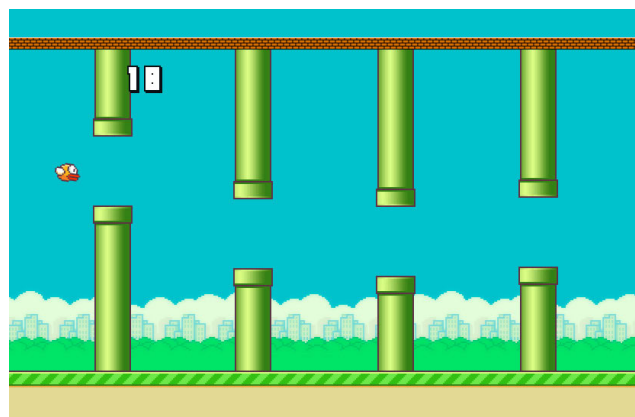


FIGURE 4. Educational video game created with the SGAME platform.

question correctly, he/she will be able to continue playing. Otherwise, the player will lose and will have to start over again. Thus, the game has one event (collide with a pipe) whose triggering causes a learning object to be shown and one reward (continue playing instead of ending the game) that the player can obtain by consuming this learning object. The goal of the game is to achieve as many points as possible by dodging pipes. The number of pipes is infinite, so the game only ends when the bird crashes against a pipe and the player answers a question incorrectly or there are no more questions to be answered. If a question is answered correctly, the learning object containing that question will not be shown again to the player. However, if a player answers a question incorrectly (losing the current game), that player will have another chance to answer it in the subsequent games.

In order to create the educational video game with the SGAME platform, a total of 24 learning objects on databases and big data fundamentals were integrated into the game template described above. These learning objects were interactive presentations created through the ViSH Editor authoring tool available in the SGAME platform, which is described in Section III. All of these learning objects had the same structure: the first slide contained a self-grading question (in most cases a multiple choice question, although some learning objects included other types such as sorting questions), and the subsequent slides provided theoretical concepts related to the knowledge assessed by the question included in the first slide. An example of one of the learning objects integrated into the game is provided in Fig. 5 and Fig. 6: Fig. 5 shows the first slide (i.e., the one containing the question), and Fig. 6 shows one subsequent slide that provides theoretical content.

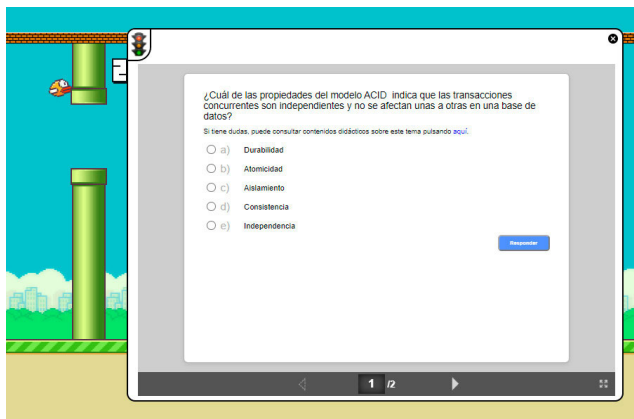


FIGURE 5. Multiple choice question integrated into an educational video game created with the SGAME platform.

4) DATA ANALYSIS

The results of the student questionnaire were analyzed by using the following descriptive statistics: mean, median, and standard deviation. In order to determine whether the obtained data is normally distributed, the Shapiro-Wilk test of normality was conducted. The results of this test show that

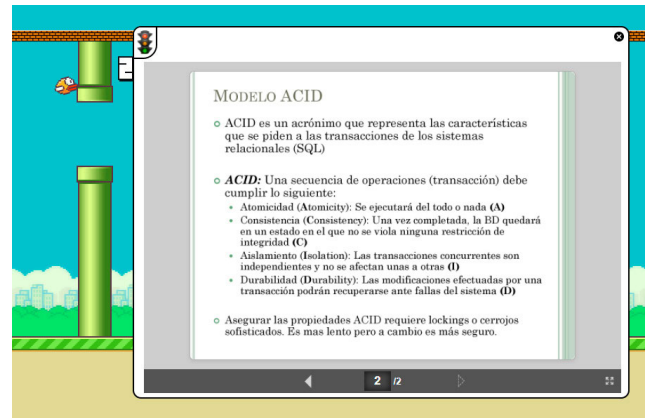


FIGURE 6. Slide with theoretical content integrated into an educational video game created with the SGAME platform.

the pre-test scores, the post-test scores, and the questionnaire scores were not normally distributed. Thus, non-parametric statistical methods were employed: pre-test and post-test scores were compared by means of a Wilcoxon Signed-Ranks Test for paired samples, and comparisons between different groups of students (e.g., between male and female students) were performed using the Mann-Whitney U test. In all cases, the correlation coefficient (r) was used as the effect size measure.

V. RESULTS AND DISCUSSION

A. TEACHERS' PERCEPTIONS TOWARD THE SGAME PLATFORM

Table 1 and Fig. 7 show the results of the questionnaire completed by 201 teachers that used the SGAME platform to create educational video games. Overall, the results of the questionnaire indicate highly positive teachers' perceptions toward the use of the SGAME platform for creating educational video games. On the one hand, most teachers had a very good overall opinion of the SGAME platform ($M = 4.0$, $MED = 4.0$, $SD = 0.9$): nearly 75% had a good

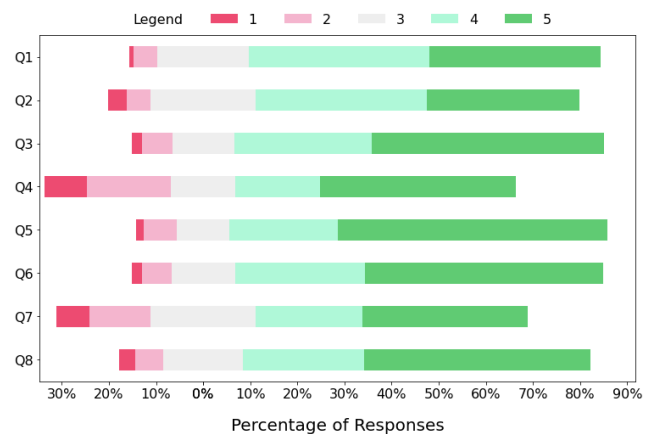


FIGURE 7. Distribution of responses to the five-point scale questions of the teacher questionnaire.

TABLE 1. Results of the teacher questionnaire (N = 201).

Question	M	MED	SD
Q1: What is your overall opinion on the SGAME platform? (1 Poor – 5 Very Good)	4.0	4.0	0.9
Q2: How would you describe the experience of learning how to use the SGAME platform? (1 Very difficult – 5 Very easy)	3.9	4.0	1.0
Please, state your level of agreement with the following statements (1 Strongly disagree – 5 Strongly agree):			
Q3: In general, the games created with the SGAME platform are useful for education.	4.2	4.0	1.0
Q4: The games created with the SGAME platform are useful for childhood education.	3.7	4.0	1.4
Q5: The games created with the SGAME platform are useful for primary education.	4.3	5.0	1.0
Q6: The games created with the SGAME platform are useful for secondary education.	4.2	5.0	1.0
Q7: The games created with the SGAME platform are useful for higher education.	3.7	4.0	1.3
Q8: The games created with the SGAME platform are useful for special-needs education.	4.1	4.0	1.1
	Yes (%)	No (%)	
Q9: Would you recommend the SGAME platform to other teachers?	96.5	3.5	

or very good opinion, whereas only 6% expressed in the opposite direction. Another evidence of the high teacher acceptance of the SGAME platform was that an overwhelming majority of teachers (96.5%) stated that they would recommend other teachers to use the platform for creating educational video games. On the other hand, most teachers found it easy to create educational video games through the SGAME platform ($M = 3.9$, $MED = 4.0$, $SD = 1.0$). Nevertheless, it is worth pointing out that around 9% of the surveyed teachers perceive the platform as hard to use.

Among the teachers who declared to have medium, medium-to-high or high prior experience with educational technology, this percentage decreases to approximately 5%.

When asked about the usefulness of the educational video games that can be created with the SGAME platform, teachers agreed, on average, that these games are useful for education ($M = 4.2$, $MED = 4.0$, $SD = 1.0$). Indeed, nearly 80% of the surveyed teachers agreed with this statement whereas only less than 9% disagreed.

When teachers were asked about the usefulness of the games created with SGAME for specific educational levels, these games were found useful for all of them, although some differences arise. Teachers indicated that the games created with the SGAME platform are slightly more useful for primary education ($M = 4.3$, $MED = 5.0$, $SD = 1.0$), secondary education ($M = 4.2$, $MED = 5.0$, $SD = 1.0$), and special-needs education ($M = 4.1$, $MED = 4.0$, $SD = 1.1$), than for childhood education ($M = 3.7$, $MED = 4.0$, $SD = 1.4$) or higher education ($M = 3.7$, $MED = 4.0$, $SD = 1.3$). The differences between the scores given by the teachers for primary, secondary and special-needs education, and those given for childhood and higher education were

found to be statistically significant with a small effect size ($0.16 \leq r \leq 0.21$).

In order to delve into this issue, for each educational level, the scores given only by teachers of that educational level were analyzed. These results are shown in Table 2. All differences between the scores given by all teachers and those given only by the teachers of a specific educational level were found to be non-statistically significant with a negligible effect size. Based on the obtained results, it can be concluded that the educational video games that can be created with the SGAME platform are perceived by the teachers as useful for all educational levels. These results are consistent with previous research that pointed out that game-based learning is effective at all levels of education and hence it is not limited to a certain period of age [7].

TABLE 2. Teachers' perceptions on the usefulness of the games created with SGAME for their educational level.

Question	N	M	MED	SD
Please, state your level of agreement with the following statements (1 Strongly disagree – 5 Strongly agree):				
Q4: The games created with the SGAME platform are useful for childhood education.	32	3.8	4.0	1.3
Q5: The games created with the SGAME platform are useful for primary education.	72	4.4	5.0	0.8
Q6: The games created with the SGAME platform are useful for secondary education.	71	4.1	5.0	1.1
Q7: The games created with the SGAME platform are useful for higher education.	54	3.8	4.0	1.3
Q8: The games created with the SGAME platform are useful for special-needs education.	11	4.1	5.0	1.1

The obtained results also show that teachers believe that the games created with SGAME are more useful when used in primary, secondary and special-needs education, than when used in childhood or higher education. A possible reason for this finding is that, on the one hand, young children can experience more difficulties using the games, and, on the other hand, the games can be perceived as too childish or not serious enough for a higher education setting.

The questionnaire completed by the teachers included a final open-ended question in which they could provide suggestions, opinions, or any other comment they wished. A total of 76 out of the 201 teachers who filled out the questionnaire left a comment. Of these 76 comments, 42 (55.3%) were positive, whereas 4 (5.3%) were negative, and the remaining 30 (39.5%) merely included suggestions to improve the SGAME platform. In the positive comments, teachers mainly expressed their appreciation for the initiative and praised the SGAME platform. Some of them specifically highlighted the usefulness of the SGAME platform as an educational tool, its potential to motivate learners through game-based learning experiences, and its innovative character. Furthermore, some teachers emphasized how easy it was for them to create games with the SGAME platform. Notwithstanding, three out of the

four teachers that left negative comments indicated that they found the platform not very intuitive or hard to use. There was only one other complaint in the negative comments, which was a complaint made by two teachers about the quality of the game templates currently provided by the SGAME platform.

Regarding the suggestions made by the surveyed teachers to enhance the SGAME platform, there were two suggestions that stand out of the rest for having been made by a significant percentage of the teachers. The first one was to add more game templates to the SGAME platform, increasing this way the possibilities for conducting game-based learning experiences. In this regard, some teachers specifically claimed for more game templates with mobile and tablet support. The second of the suggestions that stands out was to provide more resources aimed at helping teachers using the SGAME platform for conducting game-based learning experiences. Specifically, teachers ask for more video tutorials and to extend the SGAME user manual. Other noteworthy suggestions made by the teachers were adding more sequencing options and grading settings, and providing new ways to easily add content to the games.

In view of the results reported in this section, it can be suggested that the SGAME platform enables teachers to easily create useful educational video games for all education levels, and that teachers are, in general, satisfied with the features that the SGAME platform provides for this purpose.

B. STUDENTS' PERCEPTIONS TOWARD THE GAMES CREATED WITH THE SGAME PLATFORM

Table 3 and Fig. 8 show the results of the questionnaire administered to collect students' perceptions toward the educational video game created with the SGAME platform previously described.

TABLE 3. Results of the student questionnaire (N = 71).

Question	M	MED	SD
Q1: What is your overall opinion on the educational game? (1 Poor – 5 Very Good)	3.9	4.0	0.9
Please, state your level of agreement with the following statements (1 Strongly disagree – 5 Strongly agree):			
Q2: The educational game was easy to use.	4.5	5.0	0.8
Q3: The educational game helped me learn.	4.2	4.0	0.8
Q4: The educational game was appealing and motivating.	3.9	4.0	1.0
Q5: The educational game made learning fun.	3.8	4.0	1.1
Q6: The educational game was suitably integrated into the virtual learning platform from which I accessed them.	4.5	5.0	0.8
Q7: I would like to use similar educational games again.	4.1	4.0	1.2
	Yes (%)	No (%)	
Q8: Would you recommend the educational game to other peers?	90.1	9.9	

The results of the student questionnaire show that students had a positive overall opinion on the game (M = 3.9, MED = 4.0, SD = 0.9), that they strongly believe that the game was easy to use (M = 4.5, MED = 5.0, SD = 0.8),

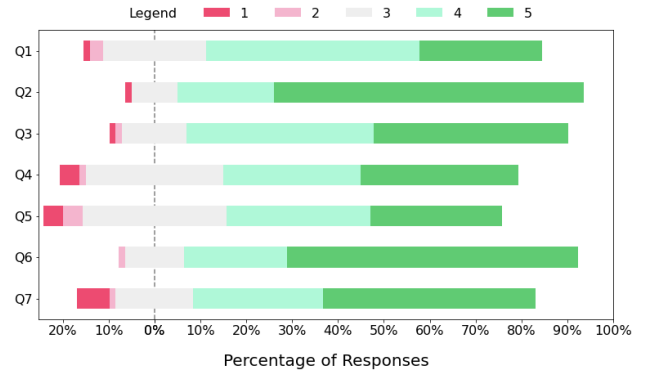


FIGURE 8. Distribution of responses to the five-point scale questions of the student questionnaire.

and that they found it beneficial for their learning (M = 4.2, MED = 4.0, SD = 0.8). Furthermore, students thought the game was appealing and motivating (M = 3.9, MED = 4.0, SD = 1.0) and that it made learning fun (M = 3.8, MED = 4.0, SD = 1.1). Another fact that evidences the high acceptance achieved by the examined educational video game among students was that, in general, they expressed to be in favor of using similar games in the future (M = 4.1, MED = 4.0, SD = 1.2). Moreover, a vast majority of students (90.1%) stated that they would recommend the game they played in this experience to other peers.

Regarding the access to the game through the Moodle platform of the course and its integration with the other materials, students agreed that the game was suitably integrated into Moodle (M = 4.5, MED = 5.0, SD = 0.8). This result proves that the feature provided by the SGAME platform to export games as SCORM packages allows to successfully integrate these games into virtual learning environments supporting the SCORM e-learning standard.

Regarding gender differences, no statistically significant differences were found in any of the questionnaire items when the scores given by male and female students were compared, concluding that students' perceptions toward the game were not affected by gender.

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 game-based learning experience and others emphasize the usefulness of the game for acquiring knowledge when introducing a new topic. Some students also suggest to incorporate a real-time leaderboard in order to foster competition.

The results obtained from the student questionnaire provide evidence that playing educational video games created with the SGAME platform can positively impact students' motivation. These results are consistent with the current body of knowledge of the game-based learning field [1]–[8], and specifically with those previous works that examined the use of games created with the SGAME platform [32], [33]. In this regard, it should be remarked that, although previous game-based learning experiences with games created with the

SGAME platform have been reported before, the one reported in this article is the first one that has been conducted online and remotely.

C. INSTRUCTIONAL EFFECTIVENESS OF THE GAMES CREATED WITH THE SGAME PLATFORM

The results of the pre-test and the post-test carried out to measure the students' learning gains are shown in Table 4. The average score for the pre-test was 3.6/10 (MED = 3.7, SD = 2.7), whereas the average score for the post-test was 8.1/10 (MED = 8.8, SD = 1.7). The learning gains were calculated as the difference between post-test and pre-test scores and their average value was 4.6 (MED = 4.5, SD = 3.0). The difference between post-test and pre-test scores was found to be statistically significant with a large effect size ($r = 0.59 \geq 0.5$). These results evidence that the educational video game created with the SGAME platform produced very positive impacts on students' learning and that it succeeded in increasing the students' knowledge related to databases and big data.

TABLE 4. Results of the pre-test and the post-test (N = 79).

	M	MED	SD
Pre-Test	3.6	3.7	2.7
Post-Test	8.1	8.8	1.7
Learning Gains	4.6	4.5	3.0
Wilcoxon Signed-Ranks Test for Paired Samples			
p-value	< 0.001		
Effect Size (r)	0.59		

The difference between the learning gains experienced by male and female students was found to be non-statistically significant with a negligible effect size. Thus, it can be stated that the instructional effectiveness of the educational video game created with SGAME was not affected by gender.

The results reported in this section provide strong evidence that playing educational video games created with the SGAME platform can positively impact students' learning outcomes. These results, which are consistent with prior research in game-based learning [1]–[8], add more value to the current body of knowledge of this research field by providing further evidence that educational video games created through teacher-oriented authoring tools can be beneficial for students' learning when they are appropriately designed and used.

It is worth pointing out that the results reported in this section are aligned with those reported by the single prior work that analyzed the instructional effectiveness of educational games created with the SGAME platform [33]. This prior work also found that the learning gains attained by the students as a result of playing games created with the SGAME platform were statistically significant with a large effect size. In this regard, it should be remarked that this prior work, not only provides evidence that game-based learning experiences conducted with games created through the

SGAME platform can be effective from a pedagogical point of view, but also that these experiences can be as effective as traditional teaching in terms of knowledge acquisition and, at the same time, much more effective to increase student motivation.

VI. CONCLUSION AND FUTURE WORK

This article presents a teacher-oriented authoring tool called SGAME, which aims to empower teachers to easily create educational video games by integrating learning objects into pre-made games. This article also presents an evaluation of this tool from the teachers' perspective, as well as a case study examining the effect of the educational video games it allows to create on students' perceptions and learning outcomes. The results of this article provide strong evidence that SGAME is an easy-to-use authoring tool capable of allowing teachers to create motivating and effective educational video games for all educational levels.

This article contributes to fill two important research gaps in the game-based learning field. On the one hand, it alleviates the lack of studies examining teachers' perceptions toward teacher-oriented authoring tools for educational video games. On the other hand, it also alleviates the lack of studies analyzing the students' perceptions toward games created with such tools, as well as the instructional effectiveness of these games. Moreover, the reported case study provides further evidence of the benefits of using educational video games.

This article also makes a very valuable contribution by presenting SGAME, a new and innovative educational game authoring tool freely and publicly available to the educational community, which has been already used by more than 1,000 users worldwide to create their own educational video games. In this regard, it should be mentioned that the SGAME software has been released under an open source license, thereby enabling its use, distribution, study, adaptation and enhancement by the research and educational communities. Regarding the innovative character of this work, it must be taken into account that the approach employed by SGAME to enable teachers to create educational video games is unique and very different from those used by existing game authoring tools. On the one hand, this approach allows any teacher with basic computer skills to create educational video games by reusing existing games instead of developing games from scratch, which is complex, time-consuming and expensive. On the other hand, this approach allows teachers to tailor the educational video games to their specific settings and needs by integrating learning objects of their choice. In this regard, it should be highlighted that the same workflow is used to create games of different genres and for teaching different subjects. Furthermore, teachers can easily integrate the educational video games they create with SGAME into any virtual learning environment that supports the SCORM e-learning standard, thereby enabling the integration into the major learning management systems including Moodle, Sakai and Blackboard.

Although this work provides solid evidence that SGAME is a useful tool for empowering teachers to conduct effective game-based learning experiences at all educational levels, some limitations should be taken into account. First, the teachers' perceptions toward the SGAME platform were evaluated using convenience sampling, since only those teachers who volunteered participated. Thus, the results of this evaluation could be influenced by volunteer bias. Secondly, it should also be noted that the usability of SGAME was assessed based solely on the perceptions of the participating teachers. Lastly, although substantial evidence has been provided so far regarding the usefulness of the video games that can be created by means of the SGAME platform, further studies with large samples are needed to examine the use of these games in different educational settings and in combination with various instructional approaches.

In addition to the limitations of the conducted research, some limitations of the SGAME platform presented should also be taken into account. The major of these limitations is that, although SGAME allows to create educational video games of different genres, the specific types of games that can be created are limited by the game templates offered by the tool. This limitation can be drastically reduced by increasing the number of game templates available. However, it should be considered that teachers cannot modify the gameplay of the game templates, only the way in which they interact with the integrated educational content. In this regard, another limitation is that the connection between this content and gameplay is not as stronger as it could be if the educational video games were developed from scratch. Another limitation of the current version of SGAME is that only learning objects compliant with SCORM can be integrated. Although SCORM is by far the most widely used standard for packaging digital educational content, not all authoring systems support it. A last noteworthy limitation of the current version of SGAME is that it only allows to create web-based games, which limits the game templates that can be used.

The roadmap for SGAME includes the future development of several new features that will reduce several of the aforementioned limitations, and that will also meet the current teachers' demands. These features will allow the integration of learning objects compliant with other standards besides SCORM such as xAPI and Moodle XML. Another interesting feature that will be developed is the support of new advanced sequencing options, which will enable the authoring of adaptive educational video games, which will be capable of tailoring their behavior according to the learners' performance in real time. Furthermore, we plan to implement new versions of the SGAME API in order to allow the creation of educational video games that are not web-based, for instance, games developed as desktop applications or as Android or iOS native applications. Lastly, new game templates will be added to the SGAME platform, increasing this way the possibilities of the users to create educational video games and conduct game-based learning experiences.

The work presented in this article opens up new opportunities for future research. Firstly, further research should be conducted to examine the effects of game-based learning experiences conducted using games created with teacher-oriented authoring tools like SGAME in different educational settings. In this regard, taking into account that a wide range of instructional approaches can be used to conduct these game-based learning experiences [15] and that these approaches influence the instructional effectiveness [16], more research is also needed to investigate this issue in order to determine the most adequate approaches. Another interesting future line of research, which is related to adaptive learning, would be to compare the effectiveness of adaptive and non-adaptive educational video games created with SGAME. Finally, future research could also compare educational video games created by means of different teacher-oriented authoring tools and game engines.

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