Adoption of serious games by teachers: the analysis method of structure, interface and use

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Article Info	ABSTRACT
	In this article, we determine how to facilitate the analysis of serious games so that teachers could effectively integrate them in their teaching. The aim is to identify the mechanisms that would make serious games exploitation useful. We propose a method for the analysis of serious games that is based on the separation of their components along three phases. In addition, we set up a platform based on a data analysis process that is composed of six steps that help to set the basis of a verification procedure that targets the content of a game and thus facilitates the work of teachers through effective implementation of serious games as teaching strategies (TIC). The obtained experimental results show that 82.5% of the study participants expressed that the use of the platform has helped them to change their perspective on the need to use serious games as an educational tool.

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1. INTRODUCTION

Currently, digital technology has taken over most areas of our lives, including in education. At a time when the time is reserved by users for electronic media has increased which generally has made video games a favorite hobby. The serious game (SG) is a new tool to learn in a ludic way and is increasingly present in the world of teaching. They cover almost all areas [1]–[3]: sciences, economics, politics, management, health, and ecology. Today, the new generation of learners (NG) has very different expectations, demands, and aspirations. The NG is adapted to the culture of video games, since childhood, and one of its salient characteristics is the heavy use of technical/technological devices. Therefore, it is not easy for this NG to adapt to the traditional pedagogical methods on which teaching is generally based on. To achieve the intended educational results and create a favorable climate, teachers must motivate their learners and provoke interaction. Researchers [4], [5] claim that a teacher's educational choices can be decisive in how students engage in a course. Likewise, Sauvé *et al.* [6] confirm that educational activities should be diversified to give students the opportunity to make choices and break out of the routinely maintained methods and approaches. According to Hmelo-Silver and Barrows [7], teaching is a complex task and must use a set of strategies to make learning effective. Indeed, Douglas *et al.* [8] show that teachers should focus on improving their teaching methods by adopting a variety of teaching methodologies, technics, and material. Moreover, according to the researchers [9], it is essential that the teaching style must be effective enough to be well understood, and that learning, as an activity, can be conducted with learners. Besides, the environment in which learning takes place must adapt to the needs and expectations of learners. Game-based pedagogy could be a solid mechanism for learning, especially during times of crises and pandemics. Lately,

and still, we have noticed how that many digital tools are important to our life in general, and to education in specific. Several studies [10], [11] confirm the utility of SGs in the field of education. Indeed, the studies of [12]–[14] show their contributions in terms of motivation and attractiveness for learners.

One of the main facilitators of game adoption in the learning process is the teacher. Therefore, this section explains, through some studies, the role these controlling agents are ready or not, to SGs as a teaching/learning strategy. Hence, several studies [10], [11], [15], evaluate the effectiveness of the use of SGs in the results of the students. To our knowledge, few studies have been interested in the perception of the teachers, especially in regard to the adoption of such opportunities in their normal teaching practice. Indeed, if teachers are not motivated, or if they lack a positive attitude towards the implementation of SGs in a teaching-learning sequence, it will be difficult for them to adopt a game-based pedagogy. Thus, the studies of [16], [17], have tried to show to what extent the role of teachers is crucial in the creation of learning environments based on the game. Beddaou *et al.* [18] confirm that the relevance of an SG depends on the nature of the game itself, but also on how it is used in the teaching-learning process. Becker [19] too asserts that a game must necessarily be tested by the teacher before been the subject of any pedagogical integration. In addition, Kangas *et al.* [20] points out that adopting SGs requires the involvement of teachers before, during, and after any game-based intervention. Studies from [21], [22] state that teachers do not easily integrate SGs into their actual teaching practices. Indeed, according to Hébert *et al.* [23], assert that there is a need for experimental research that addresses the challenges of implementing game-based pedagogy in various classroom contexts, taking into account the obstacles which teachers themselves are confronted to optimize this methodology.

The process of adopting a game-based pedagogy requires, unconditionally, accompanying teachers with tools that facilitate understanding and effective implementation during a learning activity. The classification of Djaouti *et al.* [24], in fact, has helped to classify serious games on a website entitled: Scientific Laboratory for Research on Video Games (Ludoscience). However, the scope of this classification remains limited for teaching needs due to the lack of any concrete correspondence between the elements of the grid and the needs expressed by the teaching staff. A simplified analysis grid, resulting from the research work of Sanchez [25], was presented on the website The Digital Games Bank of the Academy of Montpellier. But the latter focuses on commitment, autonomy, social interactions, freedom, rules and rewards, mistakes, failures, and other emotional aspects, as well as the content of the game. Yet, Mathieu [26] proposed an analysis grid that targets serious games for science and technology teaching based on the research work that Becker proposed [19]. The study that is conducted by Emin-Martinez [27] proposed an adoption model based on Rogers' diffusion of innovation theory [28]. According to Surry and Farquhar [29], this theory helps to better understand and facilitate the adoption of new educational products. Rogers' theory has been widely applied to various educational technologies [30] including SGs with the study of Kebritchi [22].

The purpose of this research work, on one hand, is to propose a method of analysis to evaluate the ludic and pedagogical potential of SGs. On the other hand, to establish an environment facilitating the understanding and effective integration of SGs in the teaching process. After this introduction, the second section is reserved for the presentation of the research method, which presents the proposed method of analyzing SGs and the used experimental protocol to evaluate this method. Then, the third section is devoted to the analysis of the obtained results from the experiment and the discussion of the results. Finally, the conclusion is presented in the fourth section.

2. RESEARCH METHOD
2.1. Pedagogical act in the case of a serious game

Recent research on the integration of SGs into the teaching process has undergone significant development. Many researchers have shown that the integration of SGs in education has a positive impact on the learning of learners. Silseth's study [31] states that SGs are valuable tools for facilitating dialogue in the classroom. However, many factors prevent the effective integration of these games in the educational environment. Indeed, the study by Arnseth *et al.* [32] asserts that there are still few empirical studies exploring how games are used in education. It is necessary, according to Molin [33], to examine how teachers position themselves concerning games. In general, the proper functioning of an SG during a game-based learning situation is conditioned by the establishment of coherent and clear communication between the teacher, the learner, and the game to obtain the best ratio between the pleasure of the game and the teaching effectiveness. We have defined seven relationships in our study of the analysis of the pedagogical act in the case of a serious game. Figure 1 presents a diagram of the pedagogical act in the case of a serious game.

Thanks to this study, it can be ensured that the role of the teacher is to choose the SG, which is best suited to his learners, his teaching objectives, his method of work, and also to help the learner achieve the intended objectives. Table 1 presents the concept of the links between the teacher, the learner, and the game. Thanks to this analysis study, which targeted the position of the game concerning the teacher and the learner, we have defined two verification processes for the content of the game used by the teacher to judge the relevance of the game for a specific learning situation. Figure 2 shows a description of the steps in the SG verification process. The effective integration of SG into the teaching process requires a double check. On the one hand, the content of the game must be compatible with the knowledge of the learners and on the other hand, the content of the game must meet the pedagogical needs of the teacher.
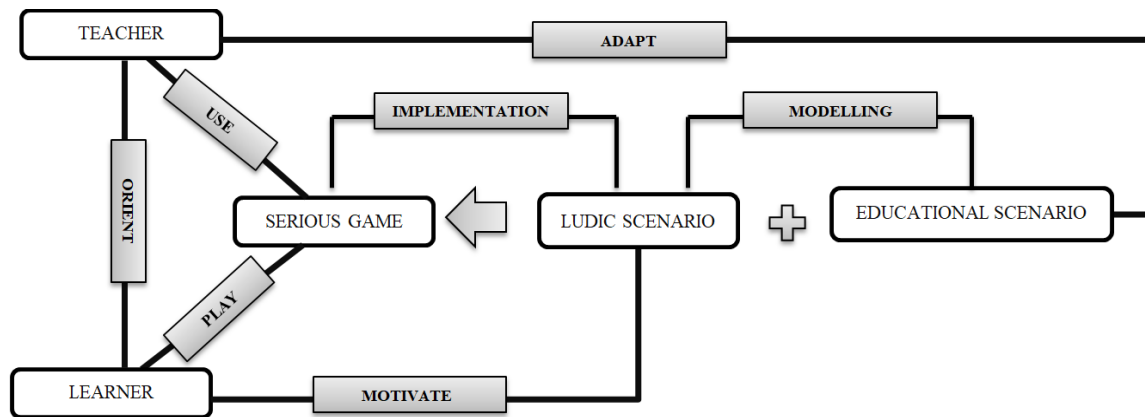

Figure 1. Diagram of the pedagogical act in the case of a serious game

Table 1. Pedagogical relationships in the learning situation through serious game

| Relationship	Role
PLAY	The learner acquires knowledge through a game-based learning situation. The learner can be in contact with the sources of knowledge, to build their knowledge as effectively as possible.
USE	The teacher must have a good knowledge of the used games in order to know what disciplinary knowledge and transversal skills are worked in these games.
ORIENT	The teacher would observe the learner and systematically correct or assist the learner.
ADAPT	The teacher chooses the game and then adapts it according to the content and the targeted skills. Moreover, it organizes space and time (place, material, duration...).
MODELLING	The educational content can be modelled as a meaningful and intelligible object. This modelling constitutes pedagogical structuring in a ludic context.
IMPLEMENTATION	This is step reserved for the design of the elements constituting the game.
MOTIVATE	The game promotes motivation in the face of a given subject. Indeed, it creates a positive pedagogical climate in which the error is de-dramatized and the center of attention is moved from the pedagogical content to the ludic task to be performed.
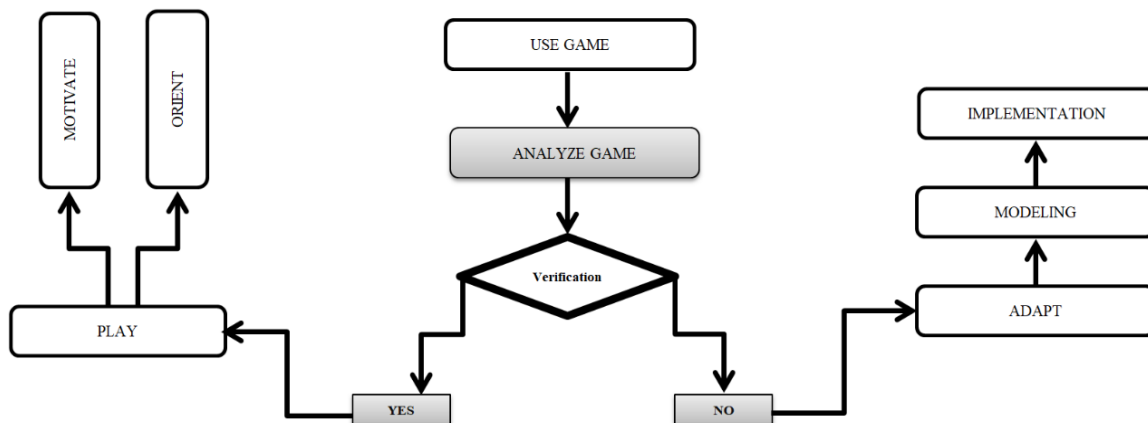
Figure 2. Steps in the verification process

2.2. Serious game analysis steps

Although several studies confirm the positive impact of SGs by basing on learners' learning outcomes, there is still a lack of appropriate measures and methods to assess the different quality characteristics in SGs. Also, the level of expertise of the designers and developers of SGs influences their qualities. In addition, only the teacher can choose adapted games to the prerequisites of his learners, his pedagogical objectives, and his work method. Since some knowledge may be transmitted more effectively through a lecture course, others will need an SG to allow learners to acquire it. Therefore, it will be difficult to judge the qualities and effectiveness of an SG without methods of evaluation of the different ludic and educational components of the game.

Calderón *et al.* [34] summarize the characteristics that have been used in the literature to evaluate serious games in 18 characteristics. The 18 characteristics are game design, user satisfaction, usability, usefulness, understandability, motivation, performance, playability, pedagogical aspects, learning results, engagement, user experience, efficiency, social impact, cognitive behavior, pleasure, acceptance, and user interface. The study of [35] shows that most approaches to how to evaluate educational games do not provide an explicit definition of the purpose, measures or, data collection instruments.

Given the lack of methods that facilitate the analysis of SGs, we have proposed a method of analysis in three phases, called SIU (structure, interface, and use) that allows to ensure the balance between ludic elements (motivation and commitment) and educational content (effectiveness of learning). Figure 3 shows a description of the steps in the proposed analytical method:

a. Structure phase: ensures the level of compatibility between the pedagogical aspect and the ludic aspect of an SG. This phase allows giving results on the level of compatibility of the educational objectives to be achieved with the ludic scenario of the game.

b. Interface phase: confirms the level of compatibility of the utility and usability of an SG with the educational objectives and characteristics of the learners. This phase permits giving results on the quality of the technical elements of the game environment and the quality of the interactions provided to the learner to achieve defined objectives.

c. Use phase: ensures the level of compatibility of the understanding conditions and the degree of knowledge acquisition of an SG with the characteristics and knowledge of the learners. This phase provides results on the understanding and control conditions of the learners (total score, number of mistakes, time spent on each task, and others) and the degree to which knowledge and skills are acquired.
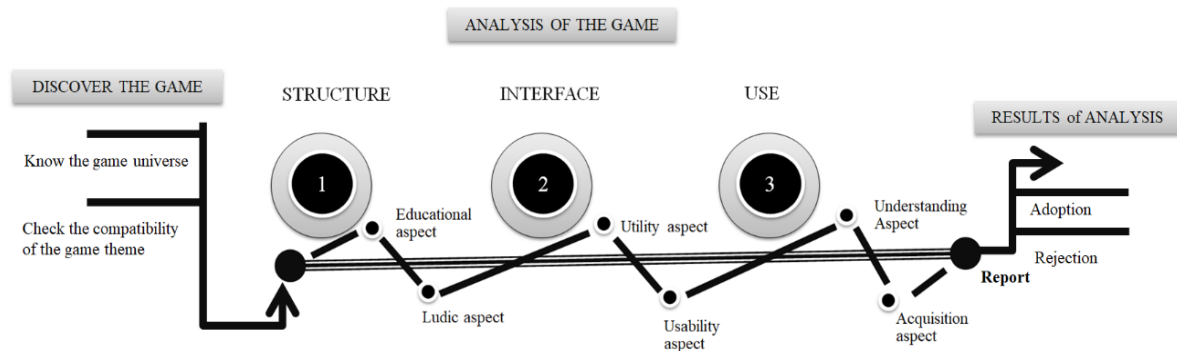

Figure 3. Steps in the analysis of a serious game

The SIU method is based on a hierarchical representation at several levels representing all the elements constituting the SG. Figure 4 shows an example of a hierarchical representation for the intrinsic motivation factors. The SIU method is based on a step-by-step control and decision-making process to analyze the SG effectively. Figure 5 presents an extract of the evaluation of the validity of the content of the SG.

The SIU method makes it possible to determine the evaluation criteria to measure the ludic and pedagogical dimension of an SG to judge the relevance of the game for a specific learning situation. Table 2 presents the criteria for assessing the validity of the SG content. The SIU method makes it possible to exploit the potential of SGs in education without involving teachers in overly complex procedures that require computer skills and also to help teachers to understand and effectively implement SGs during a learning activity.
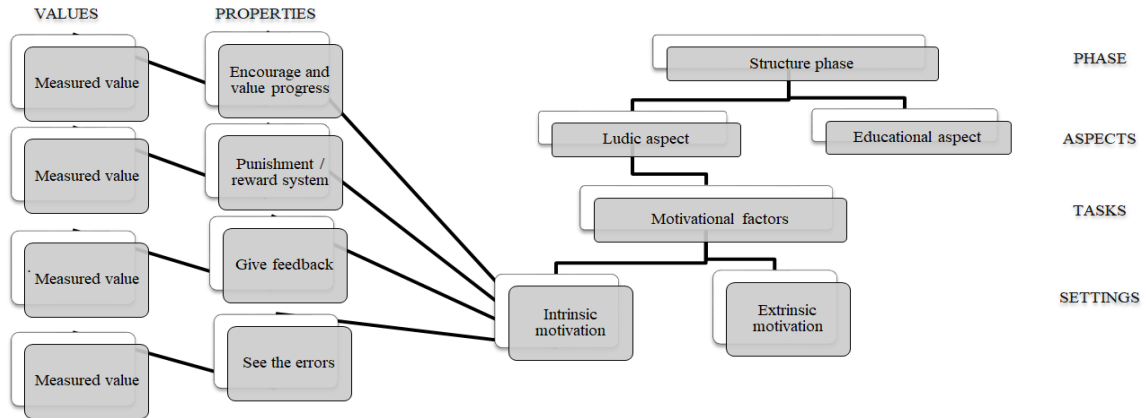
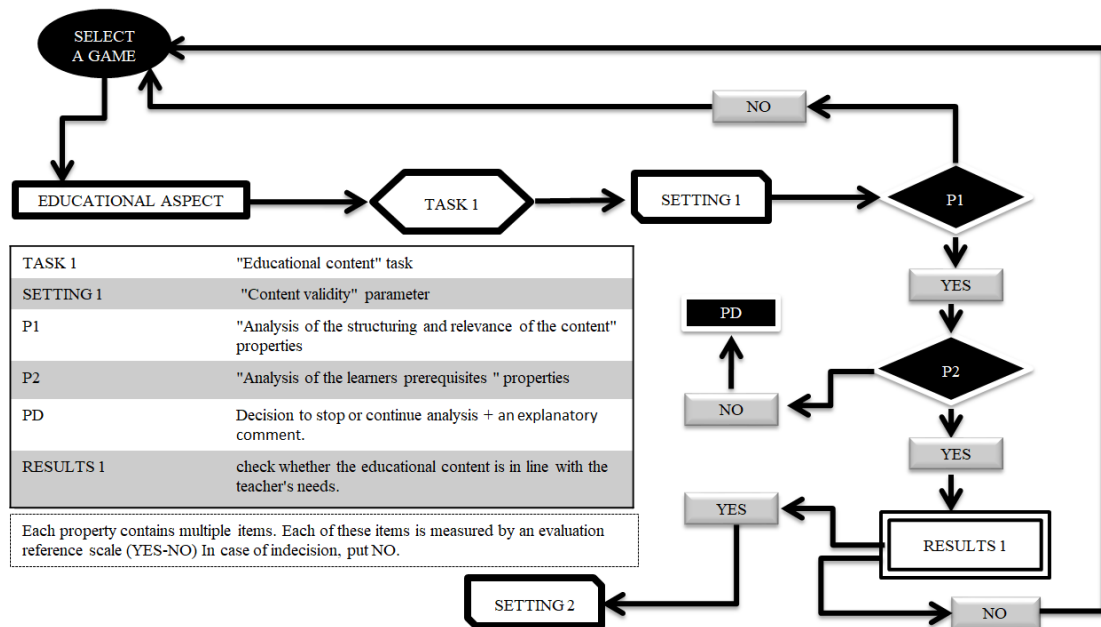Figure 4. Example of hierarchical representation for intrinsic motivation factors

Figure 5. Extract from analysis of the validity of the content of a serious game

Table 2. Criteria for evaluating the validity of serious game content

Setting	Criteria	Meaning
TASK - Educational content		
Setting 1	Relevance	Relates exactly to what is requested
Setting 2	Consistency	Logical links between the elements, everything is organized
Setting 3	Precision	Detailed, clear, concise

2.3. Evaluation of the proposed method

In this part, we present the methodology followed to evaluate our approach. This study was carried out in two stages during a period of 9 months, going from May 2020 to January 2021. The first six-month stage was devoted to the implementation of a platform based on our approach, called serious game analysis (SGA). Then, in the second three-month phase, we have established an evaluation protocol that measures the efficiency and usefulness of the approach we are proposing.

2.3.1. Presentation of the SGA platform

We have set up a digital environment that allows teachers to visualize, analyze and evaluate SGs in a six-step process: i) discover the game; ii) verify pedagogical compatibility; iii) verify motivational aspects,

iv) study the rules, constraints, and the penalty/rewards system; v) check the visual and auditory elements; and vi) study the conditions and criteria for the assessment of prior learning. Moreover, SGA users can perform three types of actions: i) perform an analysis of a game to generate an analysis report, ii) compare analysis published results by other teachers, and iii) import published analysis results to generate a personalized report. Each game has associated a list of details such as classification, number of published reports, results of analysis, and more. The teacher can then use these details to assess the quality and usefulness of the game against predefined teaching areas.

2.3.2. Experimental method

The purpose of this section is to explain the experimental protocol used to evaluate the effectiveness of the SIU method. We have realized two experiments. The objective of the first experiment is to study the usefulness and effectiveness of the SGA tool. The second experiment aims to study the appreciation of teachers and students regarding the precise evaluation criteria on the SGA tool analysis report in a real context.

a. First experiment

To validate the effectiveness of the proposed method, we performed an experimental study in five phases: i) use of the platform in a real context, ii) collect feedback from teachers on the analysis process SGs, iii) conducting a questionnaire with teachers, seeking to verify the level of perceived efficiency of the platform, iv) analyzing the collected data by questionnaire with a statistics and data management software package, and v) analysis of the results of the last two phases.

We tested our approach in using the SGA platform. For this, a sample of 40 teachers who have agreed to participate in such an experiment, 24 teachers from the Polydisciplinary Faculty of Taza and 16 teachers from the Polidisciplinary Faculty of Nador, in the following disciplines: Computer Sciences, Physics, Economics, Biology, English and French. We sent out a video and a user guide to the teachers that explained the description of the SIU method and how to use the SGA platform.

Only four of the participants are experienced users of the games and have been using them for two years. The rest are using the game for the first time. The disciplines that are interested in this study are characterized by a level of teachers' skills that are sufficient concerning the use of computer software.

The duration of the experiment is variable for each teacher, as it depends on the duration of the tested game and also on the level of the teachers' experience concerning the game. Some teachers played the game twice to familiarize themselves with the game (content, controls, how to access levels, and others). To better analyze these results, we also carried out an evaluation based on a questionnaire to assess the teachers' point of view regarding the possible use of SGs and to collect their opinions on the qualities of the platform such as the quality of the games offered, utility, interface qualities, and user satisfaction. We used a 5-point likert scale from 1 (strongly disagree) to 5 (strongly agree) to determine user responses.

b. Second experiment

To support teachers in the use of SGs in the classroom, we organized an experiment of two working sessions with four teachers in two different establishments (Polydisciplinary Faculty of Taza and Polydisciplinary Faculty of Nador). The first session was devoted to the choice of the SG by the teacher using the SGA platform. Table 3 shows the games analyzed by the teachers.

In the second session, we prepared and conducted the game session with the teachers based on the SGA report. The session consists of the game phase and the debriefing phase. The objective was to help teachers adopt SGs in their educational contexts and to observe the impact of SG on students' motivation and behavior.

Table 3. Presentation of the games of the experimental study

Game	Realization	Ludic video type	Thematic and target audience
CodeCombat	CodeCombat Inc.	Game of programming	Game teaches different programming languages (JavaScript, Python ...) as well as the fundamentals of computer science.
Leuco'war	Philippe COSENTINO	Game of immunology	Game allows students to visualize the functioning of the immune system following an infection.
Cartel euros 3000	Creatiel LLC	Game of management	Game allows students to learn management.

3. RESULTS AND DISCUSSION

Of the 40 teachers, more than 90% did not use SGs in their teaching. However, during the experiment, 65% of teachers played several times the chosen game. It is to familiarize themselves with the content and operational details.

3.1. Results

In our experiment, the SGs evaluated had diverse themes, most of which are of the type shooting game, simulation game, strategy game, and puzzle game. Player-game interactions were most often done through drop-down menus. Regarding the scoring methods, some games had a score per stage, but most had an overall score.

3.1.1. First experiment

During experimentation with the use of the SGA platform, 72.5% of teachers generate a summary report of the SG chosen. Only 10% of participants stopped the analysis in the first phase by clicking on "Content not compatible with educational objectives". However, 7.5% of teachers have identified difficulties in understanding the rules of the game and 10% of users indicated difficulties in setting assessment conditions. We also noted that 2.5% of participants analyzed two games to familiarize themselves with the learning management system (LMS) platform. Some games have been analyzed several times by different profiles.

To better analyze these results, we also performed an assessment based on a questionnaire comprising 10 questions to assess the qualities of SGA. We have added a question to check the use of SGs. Figure 6 shows the mean and standard deviation of the results of the questionnaire concerning the qualities of the platform such as the qualities of the games offered, the usefulness, the interface qualities, and the user satisfaction. Among the 40 teachers, 82.5% of teachers said the platform helped them to change their appreciation of the need to use games during a learning situation. 10% are neutral on this issue, and 7.5% disagree with it.
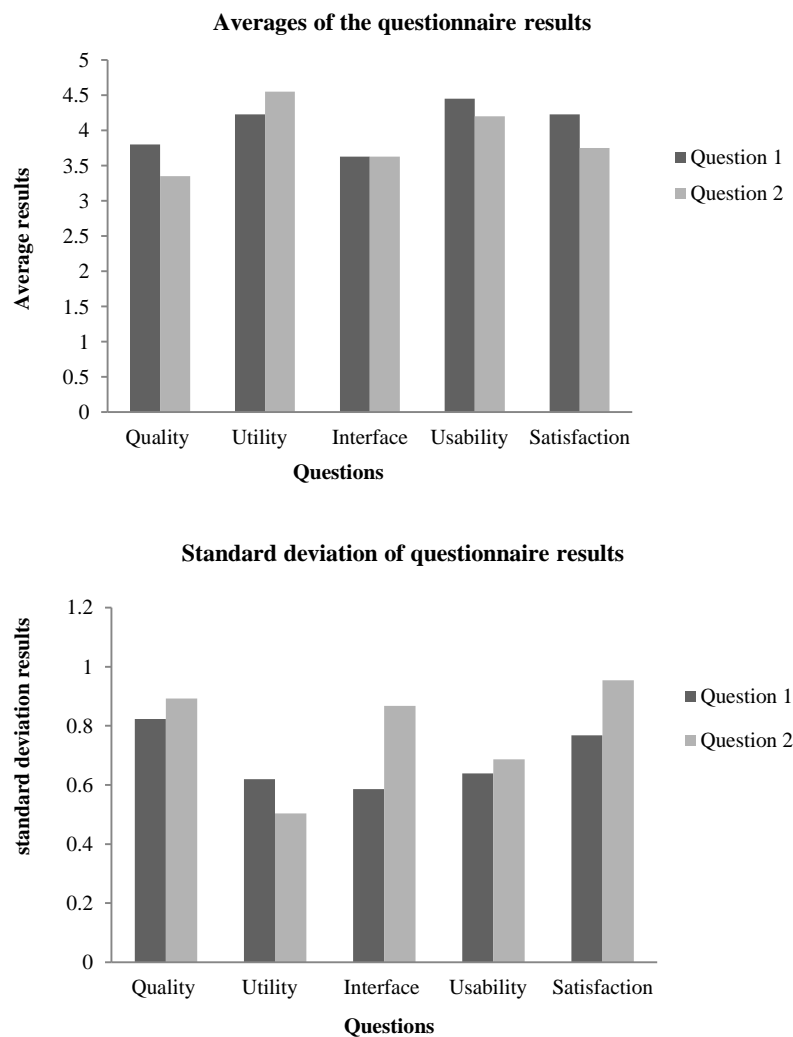

Figure 6. Mean and standard deviation of the results of the questionnaire concerning the qualities of SGA

3.1.2. Second experiment

We conducted a second experiment by following two avenues to assess the effectiveness of the proposed method. Firstly, we evaluated the effectiveness of SGs in teaching by analyzing the influence of SGs on student motivation and teacher appreciation. Secondly, we assessed the effectiveness of the SGA platform by analyzing the usefulness of the teacher-generated analysis report.

Of the 120 students that participated in the survey, 95% of students did not have a negative opinion about the value of using an SG in a learning session, and 92.3% of them found that using a game facilitates some learning. The students generally appreciated the initiative and its applicant of this type of pedagogy. The teachers agreed on the need for games during a learning situation and also the need for a prior assessment of game content. The four teachers found that the precise evaluation criteria on the analysis report generated via SGA make it possible to determine whether the objectives of the game are compatible with the intended pedagogical objectives, and therefore whether the game is effective in helping the learners. Teachers also indicated the need to add other phases to facilitate the process of adopting SGs in education.

3.2. Discussion

Serious games could be an effective strategy to improve the teaching process. However, it is necessary to assess beforehand the conformity of their contents with a specific learning situation. 75% of teachers found that the specific assessment criteria on the SGA analysis report help to determine whether the game content is effective in supporting learning. Only 25% of teachers had difficulty for several reasons, which hampered their involvement and thus their results. In addition, 20% of users used the comment feature to explain the decision to stop the analysis, allowing the system to classify games according to new criteria. Results from the questionnaire showed that 82.5% of teachers were overall satisfied with the use of SGA and agreed on the need to use SGs to improve teaching. During the experiments, teachers mentioned the need for vocational training related to game-based pedagogy.

Emin-Martinez [27] used an adoption model based on Rogers' theory [28] (the five phases and the five attributes) as a reading grid following an experience of accompanying teachers in the adoption of a game-based pedagogy. Thus, Mathieu [26] proposed an analysis grid of SGs for the teaching of science and technology-based on Becker's research work [19]. In our study, we implemented an SGA platform based on the SIU method that facilitates the understanding and effective use of SGs in education without requiring teachers to adopt new roles that are too complex and require computer skills. In general, the SIU method is characterized by three main dimensions; i) a hierarchical representation at several levels, ii) a process of control and decision-making by stages, and iii) a process of determining the evaluation criteria to assess the ludic and educational dimension of an SG. Generally, the obtained results from the experiments show that the SIU method helps and accompanies teachers in the decision-making concerning the adoption of game-based pedagogy. To make this work to be all the more relevant, some points could be improved, such as the addition of a phase to the SIU method explains the protocol for the concrete use of SGs in education according to specific cases.

4.   CONCLUSION

Currently, a serious game is an essential tool for learning and teaching. However, the research has neglected the role of the teacher in selecting and evaluating this tool for effective teaching. Also, the process of adopting a game-based pedagogy requires the accompaniment of teachers with tools facilitating the understanding and effective implementation of this strategy in education. In this article, we proposed a method for the analysis of serious games based on the separation of their components according to three phases, namely, the phase of the structure, the phase of the interface, and the phase of use. This method is characterized by three main dimensions: i) a hierarchical representation at several levels, ii) a process of control and decision-making by stages, and iii) a process of determining the evaluation criteria to assess the ludic and educational dimension of a serious game. Next, we developed the SGA tool based on the SIU method to facilitate the understanding and effective use of serious games in education without teachers having to adopt new roles that are too complex and require computer skills.

Overall, the SGA tool assessment protocol has yielded positive results relative to the usefulness and effectiveness of the analysis reports. We obtained over 75% satisfaction with the specific evaluation criteria for the SGA analysis report. In addition, 82.5% of teachers expressed that the use of the platform helps them to change their view on the need to use serious games in education. Finally, the lack of professional training for teachers on strategies for game-based pedagogy presents the first barrier to the use of the game in teaching. We believe that the addition of a phase to the SIU method could improve the accuracy of the selection of serious games for effective learning and also improve the process of adoption of serious games by teachers.

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