A Novel Tool to Predict the Impact of Adopting a Serious Game on a Learning Process

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Abstract: In recent years, the rapid development in information and communication technologies has provided the learning field with a variety of new teaching methods to motivate students and improve their skills. Serious Game (SG) is an example of these new forms of learning which constitutes an attractive way supposed to replace the classical boring courses. However, the use of SGs in classroom teaching is still limited since the choice of the adapted SG to a specific learning environment remains a challenging task that makes teachers unwilling to adopt this concept.Face to this finding, our aim is to propose a multi-agent-based simulator to predict the effect of a SG adoption in a learning environment given several game and players characteristics. As results, the simulator gives intensities of several emotional aspects characterizing learners reactions to the SG adoption. Experimentation demonstrates that the results given by the proposed tool are close to real feedbacks. This work is supposed to encourage the use of SGs by giving an expectation of its impact on e-learning processes.

1 INTRODUCTION AND MOTIVATION

Nowadays, technological progress concerns practically all the domains. In learning field, this progress has produced the concept of Serious Game (SG) which offers more attractive and motivating learning environments than classical teaching methods. SG can be defined as *"the game designed for a serious purpose other than pure entertainment"* (Julian, 2007). Currently, a lot of SGs have been developed and are available for putting into use. In the literature, several works have been proposed to evaluate SGs in real situations of learning using self-report questionnaires. They studied different evaluation criteria such as motivation (Lotfi, 2013), Flow (Freitas et al., 2014) and learners knowledge and/or competencies (Oulhaci, 2014) (Daniel et al., 2015) (Thomas et al., 2012) (Muratet et al., 2016).

Despite the multitude of evaluation works in SGs and their interest, the exploitation of this concept is still limited in learning processes (Xu and Frezza, 2011). In fact, many teachers are reluctant to take these games into their courses because they don't know if the adoption will be a success or a failure, and there is no evaluation results for them to reference. Moreover, the integration of a SG in a real learning process is a difficult task (Martens and Mueller, 2016) and does not necessarily guarantee good outcomes. Indeed, when the chosen game is not adapted to a specific learning environment, this can cause negative emotions among the learners such as boredom, anxiety or abort. This fact will, in our opinion, affect negatively the evolution of the learning process as well as a huge waste in terms of time and money. Hence, the choice of a SG must be carefully studied before integrating it in a course by considering the most important features of the learning environment including the learner-player and the SG. As a solution to this problem we propose, in this paper, a novel tool for simulating the integration of a serious game in an e-learning process. This tool allows teachers to predict the impact of a SG on their learning environments before deciding to use it. The simulator receives as input several characteristics of the game and the players, and thanks to specific functions, generates a report to predict the results of the learning environment and emotional states of learners.

The rest of this paper is structured as follows. Section 2 overviews some background information on SG. Section 3 positions the reader in the context by summarizing most of the existing work on SGs evaluation and simulation. Section 4 details the proposed model of a serious game-based environment. According to this, section 5 describes the implementation and results of our simulator. To verify the reliability

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of the proposed tool, section 6 compares the results given by the simulator to real feedbacks obtained after adopting the SG in a real learning process and gives a discussion of the case study. Finally, section 7 sums up the conclusion and outlines future works.

2 BACKGROUND ON SERIOUS GAME

A survey on the term "serious game" showed that there is no current singleton definition of the concept and provided a wide range of definitions. One of the most recent definitions of this term can be found in the PhD thesis by (Julian, 2007). He defined a serious game as: *"a computer application, which aims to combine aspects of both serious as, but not limited to, teaching, learning, communication, or further information with entertainment from the spring game"*.
Actually, SGs provide a more powerful means of knowledge transfer which can be used in several domains for different purposes such as education, ecology, military, and health-care. In fact, there is two play modes in SGs: multi-players and single-player. The multi-players mode is a mode of play involving more than one person at the same time in a shared game environment, whereas a single-player mode is a play mode designed for involving only one person. Some of SGs offer the two play modes and others are limited to only one play mode. To be more concrete, Table 1 presents some examples of existing SGs.

Table 1: Examples of serious games.

Serious Game	**Domain**	**Game Purpose**	**Multi-Players**
Navadra	Education	Educative message broadcasting	Yes
804	Military	Marketing message broadcasting	No
Rescue-Sim	Crisis Management	Training	Yes
Eye surgery	Health-care	Training	No
Aquacity Game	Ecology	Informative message broadcasting	No
Flee the skip	Corporate	Communication message broadcasting	Yes

3 RELATED WORK

The state of the art of SGs is quite rich and the existing works can be classified into several categories according to the problem type. Since we are interested in simulating and evaluating serious game-based environments; we targeted works related to these topics. Consequently, the considered works may be divided into two main groups.

The first group consists of the Non-Player Character (NPC) simulation in SGs. For example, (Ochs et al., 2009) as well as (Karim, 2014) have developed tools that model and simulate the non-player behavior in SGs to improve the NPC credibility and to increase consequently the feeling of immersion and pleasure among players.

The second group focuses on learners' assessment and evaluation during a game session. To attain this goal, many works proposed different criteria such as motivation, Flow and learners knowledge and/or competencies. For instance, (Lotfi, 2013) focused on assessing motivation basing on the motivational model ARCS (Attention, Relevance, Confidence and Satisfaction) combined with electro-physiological recordings since it represents a key factor of an efficient learning. In addition, (Freitas et al., 2014) confirmed the relevance of the use of Flow criterion to evaluate the optimal learning experience with a SG. They confirmed also the effectiveness of using self-report questionnaire as an evaluation method since it provided results conform to real feedbacks. Furthermore, the research works referenced by (Oulhaci, 2014) (Daniel et al., 2015) (Thomas et al., 2012) and (Muratet et al., 2016) focused on the learning aspect to evaluate the knowledge and/or competencies acquisition during a game session.

Let us remember that our aim is to simulate a learning environment based on a SG by taking into account the learner emotional state as well as different features representing the game. In the literature, there is no works having exactly the same purpose. On the one hand, (Ochs et al., 2009) as well as (Karim, 2014) allow us to learn about emotions which constitute a crucial factor impacting the SG progress. However, their objectives are different from ours. In fact, we propose to develop a SG simulator allowing teachers to predict the impact of adopting a SG on a particular learning process by taking into account the learner emotional state. On the other hand, the evaluation works referenced by (Lotfi, 2013) (Freitas et al., 2014) (Oulhaci, 2014) (Daniel et al., 2015) (Thomas et al., 2012) and (Muratet et al., 2016) are so important because they allow us to identify several success criteria of a serious game-based learning session. Whereas, they are all applicable after the SG use and there is no work that allows to give a prediction on learning effects using SGs.

This lack has motivated the current work aiming to propose a tool for simulating the integration of a serious game in an e-learning process. This tool allows teachers to study the impact of a SG (in terms of success degree) on their learning environments before deciding to use it. To be able to implement the simulator, we started by proposing a model of SG environments which will be described in the following section.

4 SERIOUS GAME-BASED ENVIRONMENT MODELING

Since our aim is to predict the success (or failure) of using a serious game in a learning process, the proposed model is based on meaningful success features of the considered environment. In what follows, we start by describing the selected features related to learners as well as the serious game. After that, we present the functions linking these features to each other, and finally we detail the proposed model.

4.1 Success Factors and Success Indicators

Our contribution is inspired by studies focused on criteria used to evaluate serious games (Lotfi, 2013) (Freitas et al., 2014) (Daniel et al., 2015) (Calderon and Ruiz, 2015). Thanks to the considered works, we were able to extract two feature types consisting of: ”success indicators” and ”success factors”.

The considered success indicators are: interest degree, immersion degree, motivation degree and Flow degree. These indicators are supposed to indicate the success degree of the game-based learning environment and are impacted by success factors. The considered success factors are: the game context realism, the gameplay, the game relevance and confidence, the game attention, the game challenge and the player skills. In the proposed simulator, the success factors will represent the input and the success indicators will represent the output.

For more clarity, the definition of these criteria is given in Table 2.

In the following part, we describe the different functions linking success factors with success indicators.

Table 2: Modeling Features Definition.

Feature name	Definition
Success factors:	
Game challenge	The game difficulties and problems.
Game context realism	The usefulness of game content in real life.
Gameplay	The ability of the game to be played.
Game attention	The presentation style of game content.
Game relevance and confidence	The importance and the ease of learning.
Player skills	The player aptitudes, capacities and abilities.
Success indicators:	
Flow degree	The feeling of being pleased to play game.
Immersion degree	The feeling of being involved in game.
Motivation degree	The feeling of being motivated to play game.
Interest degree	The feeling of giving concern to game content.

4.2 Links between Success Factors and Success Indicators

4.2.1 The Interest Degree

The game context realism expresses the ability of the serious game to describe real situations and concrete scenarios that can be applicable in real life. The feeling of interest is strongly linked to the context realism. In fact, when the context realism level increases, the interest becomes more and more intense. (Hidi and Renninger, 2006) distinguishes three interest degrees: **the triggered situational interest** referring to a psychological state resulting from an interest to a game-based learning process; **the maintained situational interest** referring to a psychological state that contributes to the maintenance of situational interest; and **the individual interest** characterized by more stored knowledge and more stored value for particular content than for other activity.

The proposed function, as shown in Figure 1, is inspired by five-point Likert scale which is one of the most popular psychometric scale used to measure someone's attitudes or behaviors. The passage from one state to another is conditioned by the realism of context level value. For example, the passage from the triggered situational interest to the maintained situational interest is assured if the assigned value to the context realism is equal to 3. Similarly, we attain the individual interest when the provided value is equal to the maximum value 5.

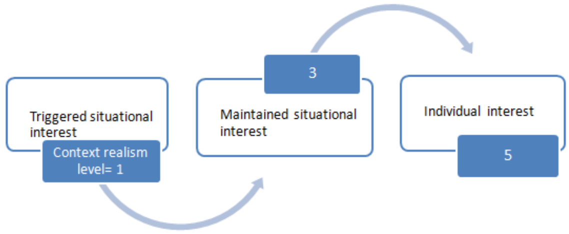

Figure 1: Evolution of Interest Degree Depending on the Context Realism Level.

4.2.2 The Immersion Degree

The immersion degree of the learner in the virtual word of the game is strongly impacted by the gameplay aspect. The gameplay aspect expresses the ability of the game to be played and includes several factors like sound elements, animations and graphical quality (St-Pierre, 2010). We propose three different immersion degrees: **the interaction** taking place while reading the rules at the beginning of the game session; **the engagement** happening when the player is actively involved in the resolution of a particular problem; and **the immersion** detected when the player is so involved in the game world that he becomes unconscious of the time and himself.

As shown in Figure 2, we propose in the same way a function containing a scale of five points to represent the evolution of the immersion degree according to the gameplay level.

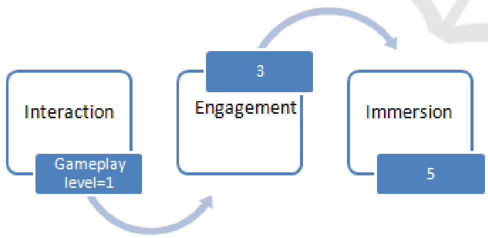

Figure 2: Evolution of Immersion Degree Depending on the Gameplay Level.

4.2.3 The Flow Degree

The most important concept used to explain subjective experience while playing games is Flow theory. (Csikszentmihalyi, 1990) defined the Flow as: *"rewarding, subjective, emotional state of optimal pleasure that arises when an individual is absorbed in either work or leisure activities that are perceived as valuable"* . This state depends on the actor skills and the activity challenge. In fact, **the Flow** state occurs when there is a perception of a balance between the skill level and the challenge level as shown in Figure 3. **Boredom** and **anxiety** are negative experiences that demotivate the player: if the player is bored, he has to increase the challenge he is facing. In contrast, if the player feels anxiety, he must increase his skills. **Apathy** is an emotion that occurs when the values of skill level and challenge level are equal but they are not maximal.

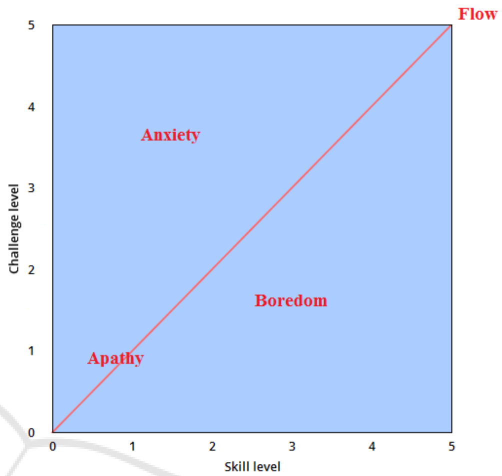

Figure 3: Relation between the Skill Level and the Challenge Level (Csikszentmihalyi, 1990).

4.2.4 The Motivation Degree

It is commonly accepted that "motivation" plays a huge role in learning, further suggesting that human beings learn best when having fun (Martens and Mueller, 2016). Basing on the motivational model ARCS (Keller, 2010), we note that the motivation level is strongly impacted by two game characteristics including the attention level as well as the relevance and confidence level. In fact, the attention level expresses the fact to attract the player attention on the presentation style of a game content. The relevance and confidence level expresses the perception of the importance and the ease of learning. Indeed, when the player believes that the level of relevance and confidence is high and that the attention level is low, a **discouragement** feeling will be occurred. Contrarily, a relevance and confidence perceived as lower than the attention level will be a source of **indifference** as illustrated in Figure 4. The feeling of **motivation** is occurred when there is a perception of a balance between the attention level and the relevance and confidence level.

The previously discussed aspects are summarized in Table 3: for each success indicator, the corresponding degrees as well as the success factors impacting it are shown.

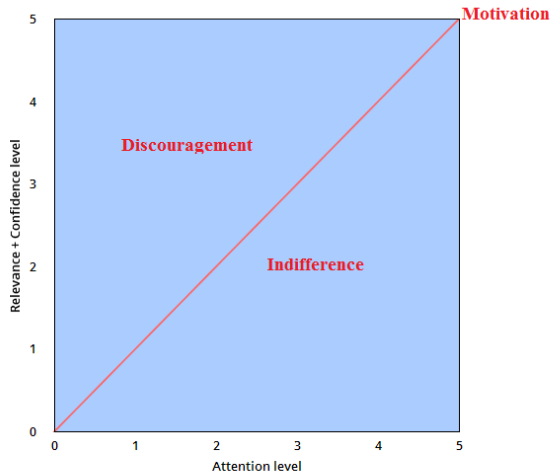

Figure 4: Relation between the Attention Level and the Relevance and Confidence Level.

Table 3: Modeling features in serious games.

Success factors	Success indicators	Corresponding degrees
Game context realism	Interest degree (Hidi and Renninger, 2006)	Triggered situational interest, maintained situational interest, individual interest
Gameplay	Immersion degree (St-Pierre, 2010)	Interaction, engagement, immersion
Game attention Game relevance and confidence	Motivation degree (Keller, 2010)	Indifference, discouragement, motivation
Game challenge Player skills	Flow degree (Csikszentmihalyi, 1990)	Boredom, anxiety, apathy, Flow

4.3 The Proposed Success-Oriented Model

In a multi-players SG environment, players control, via their keyboard and their mouse, their Player Character (PC) within the game graphical interface. The PC evolves in the game environment including entities and objects populating it and interacts with other PC and Non-Player Character (NPC is a character controlled by the game artificial intelligence). The player reactions to the changes produced in a game environment depend on his skills level, skills of other players as well as the characteristics of the game consisting of: the challenge level, the gameplay level, the relevance and confidence level, the attention level and the context realism level. The PC or the NPC can be represented by a software agent who is able to perceive other players characteristics and to make decisions basing on his information in order to adapt his characteristics to the considered game environment (Daoudi et al., 2017).

Basing on this brief description, we propose the success-oriented model of serious game-based environments shown in Figure 5.

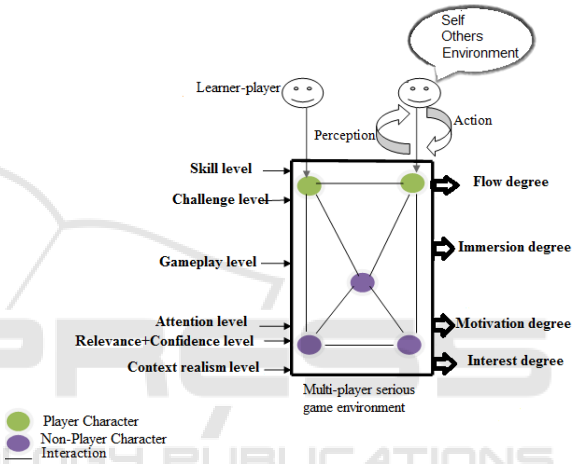

Figure 5: The Proposed Success-Oriented Model.

5 SIMULATION DETAILS AND RESULTS

In this section, we focus on the simulation work. For this aim, we start by describing the simulator implementation, after that we present the simulation process, and finally we speak about simulation results.

5.1 Simulator Implementation

A learning environment based on a SG is constituted by human and non-human players who have the capacities of perception and action. For this reason, our simulator is represented by a multi-agent system which is a set of agents interacting with each other, situated in a common environment and able to control their own behavior according to their own goals. In this work, our simulator is limited to represent a SG environment consisting in different reactive agents interacting with a game since they just have reflexes without maintaining any internal state. Since the proposed model is based on the representation of human and non-human players, the resulting simulator can be used to simulate both multi-players and single-player SGs. In fact, our system implemented, thanks to JAVA Agent DEvelopment Framework, four types of agents with different roles. In the following points, we describe the role of each agent.

- **Player Agent:** this agent represents the learner-player who is characterized by a skill level. His role consists in perceiving the others agents characteristics to update his skill level and act on the game environment.
- **PC Observer Agent:** this agent calculates the average skills of all player agents. He informs them periodically about this value in order to update the challenge value perceived by each agent player.
- **NPC Observer Agent:** the role of this agent is to inform all the player agents about the non-player agents skill levels.
- **Non-player Agent:** this agent represents the NPC of the game who is characterized by a ranking. This ranking is identified according to the difficulty degree of the game selected by the teacher using the simulator interface. This ranking is sent to the NPC observer agent to inform it about the skill level of the considered NPC.

5.2 Simulation Process

In order to clarify the followed approach, we describe, in this part, the simulation process. As illustrated in Figure 7, the main steps of the simulation process are: the data collection, the simulation execution and the results display. In the following, we detail each step of this process:

1. **Data Collection:** this first step consists in collecting data about the game environment through a questionnaire. This questionnaire is intended to teachers who wish to simulate a serious game before integrating it in a particular learning process. The teacher must quantify the game characteristics consisting of: the challenge level, the relevance and confidence level, the gameplay level, the context realism level and the attention level.
2. **Simulation Execution:** Statistics on the questionnaire responses provide numerical values representing the intensities of the previously cited features. These values are considered as the simulator inputs; their availability allows to start the simulation process. There are also other features which are collected through a graphical interface like the percentages of players having a skill level x (x between 1 and 5) and the game difficulty to determine the NPC skill level as shown in Figure 6. From the input values and according to the proposed model, PC and NPC are created to simulate the game. Thanks to specific functions connecting several game environment features, the values of these features are periodically updated.

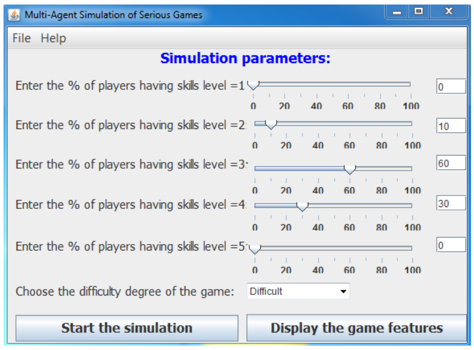

Figure 6: The Simulator Interface.

3. **Results Display:** this step consists in displaying the generated results in a graphical form.

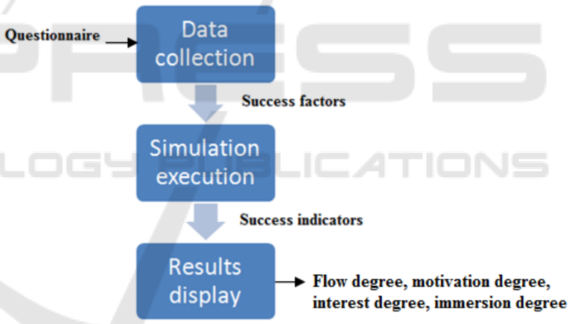

Figure 7: The Simulation Process.

5.3 Simulation Results

In order to present and to explain the form of the simulator results, we rely on the graphical interfaces obtained after the simulation of the SG ”CodeCombat” which will be described in the following section. The simulator gives two forms of results: the first displays the individual emotions felt by each player as shown in Figure 8 and the second shows a global view of the felt emotions as illustrated in Figure 9.

Figure 8 depicts the emotion intensities as percentages: it shows that the player identified by ”PC2” feels 25% of boredom, 100% of engagement, 25% of indifference and 100% of triggered situational interest. These emotions represent respectively the Flow degree, the immersion degree, the motivation degree and the interest degree.

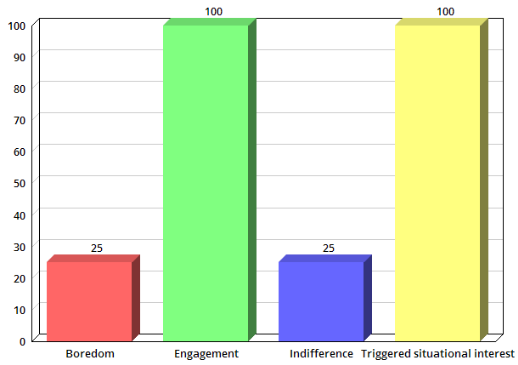

Figure 8: Emotions Felt by the Player "PC2".

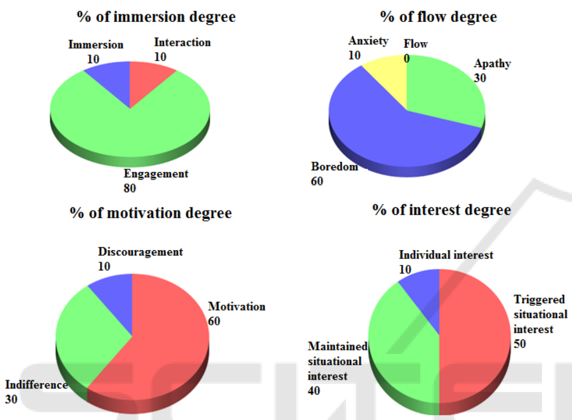

Figure 9: Percentages of Global Emotions.

Figure 9 summarizes the global emotional rates. In fact, the simulation of the SG "CodeCombat" shows that it is foreseeable to have: 60% of players feeling boredom, 30% expressing apathy and 10% feeling anxiety. About the interest degree, it is envisaged that 50% of learners feel triggered situational interest, 40% feel maintained situational interest and 10% express individual interest. Besides, the report indicates that it is expected to have: 60% of players feeling motivation, 30% expressing indifference and 10% feeling discouragement. Moreover, the study shows, as a predictable result, that 10% of learners feel interaction, 80% feel engagement and 10% express immersion.

The generated results aim to help teachers to predict the impact of adopting the game "CodeCombat" in a particular learning process by analyzing the resulting learners emotions. These values are interesting to the extent that they are consistent with the reality. In the next section, we discuss our findings by comparing the simulator results to real results.

6 DISCUSSION

In order to verify the reliability of the proposed simulator, this section aims to compare the emotional predictions to real feedbacks. The experimentation is carried out in the context of a programming course in an engineering school. It is based on the SG "CodeCombat" which is a multi-players game designed for learning programming languages. Given the purpose of this experimentation work, it is composed by two parallel steps: a simulation of the considered learning process based on the proposed tool and a real performing of a programming learning session based on "CodeCombat". Once the two steps are achieved, their results are compared. After the learning session, we proposed a specially designed questionnaire to all the participants in order to report the emotions felt by each player and to verify their conformity to the simulator results. To perform the simulation step, the responsible teacher of the previously described learning session replied to the questionnaire described in Section 5. He also gave the game features and launched the simulation using the simulator interface. Figure 10 summarizes the results obtained from the experimentation and the simulation process.

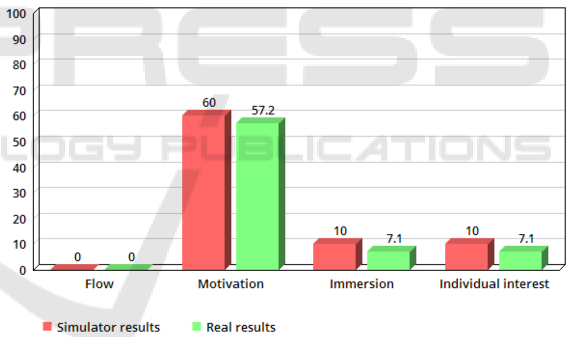

Figure 10: Comparative Chart of Simulator Results and Real Results.

As shown in Figure 10, the simulator gave results close to the reality, which is considered as a positive outcome. After the learning session, we noted that the use of a SG to learn how to code was, for the majority of learners, a good experience (57.2% felt motivation): the student discovered a modern learning tool more motivating than the classical boring courses. However, the players feedbacks showed that the game created boredom and there is no student who attained the flow state (0%). This finding is explained by the fact that the game challenge level is not appropriate to the skill level of learners. We noted also that the rate of individual interest is low (7.1%) which means that the game content does not attract players curiosity to learn new coding techniques. So, the game must propose more concrete scenarios. Concerning the immersion degree, we found that 7.1% of learners felt immersed which proves that the gameplay aspect is not well designed and should be more attractive in terms of graphical interfaces.

7 CONCLUSION AND FUTURE WORK

In this paper, we presented the results of investigations on an important challenge consisting in serious games adoption in learning processes. The paper aims to develop a tool to simulate the use of a SG before integrating it in a particular learning process. For this purpose, we proposed a success-oriented model based on emotional states of learners and different features of the SG. Then, we developed a multi-agent-based simulator which would be able to predict the impact of operating a SG on classroom teaching. On the other hand, the research got the result that came from the real operation by studying the playing experiences of the SG "CodeCombat". After that, we conducted a comparison of the simulator results with experimental results in terms of global emotional rates. Our findings show that the simulator gives results close to real feedbacks. The proposed tool is intended to teachers wishing to integrate a SG in their classical courses. It allows them to study the adequacy of the SG to the skill level of their students. So, this novel tool is able to encourage the passage from traditional to modern learning methods by giving an expectation of the effect of using SGs in a learning process.

As an immediate future work, we aim to extend the proposed simulator by considering other success indicators and factors. Furthermore, one of our future aims is to validate the simulator in different game contexts with other student populations.

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