# A Multi-Agent Simulation of Serious Games to Predict Their Impact on E-Learning Processes

Ibtissem Daoudi, Raoudha Chebil, Wided Lejouad Chaari

*Abstract*—Serious games constitute actually a recent and attractive way supposed to replace the classical boring courses. However, the choice of the adapted serious game to a specific learning environment remains a challenging task that makes teachers unwilling to adopt this concept. To fill this gap, we present, in this paper, a multi-agent-based simulator allowing to predict the impact of a serious game integration in a learning environment given several game and players characteristics. As results, the presented tool gives intensities of several emotional aspects characterizing learners reactions to the serious game adoption. The presented simulator is tested to predict the effect of basing a coding course on the serious game "CodeCombat". The obtained results are compared with feedbacks of using the same serious game in a real learning process.

*Keywords*—Emotion, learning process, multi-agent simulation, serious games.

## I. INTRODUCTION

**A**CTUALLY, technological progress concerns practically all the domains. In learning field, this progress has produced the concept of serious games which offer more attractive and motivating learning environments than classical courses. In recent years, a great interest is accorded to both the development of serious games as well as their use [1]. In this section, we start by presenting the concept of serious games, afterwards we describe the problems which motivated this work. A survey on serious games has provided a wide range of definitions. In the following, we cite the four most cited definitions in the literature.

According to Michael and Chen in 2005 [2], serious games are *"games that do not have entertainment, enjoyment or fun as their primary purpose"*. In 2005, Zyda [3] defined serious games as *"a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives"*. In 2007, Sawyer [4] defined serious games as *"any meaningful use of computerized game/game industry resources whose chief mission is not entertainment"*. In 2007, Alvarez [5] 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"*. This definition is supported by the following equation [5]:

Serious game = serious dimension + game dimension

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In this work, we adopt the last definition of serious games. The previously cited definitions have presented serious games regardless to the application field and the targeted population. In fact, serious games can be used in several domains such as education, ecology, healthcare, defense, communication, advertising, sport, politics and business. It is intended for all age groups including children, adolescents, adults and older people [6]. There is two play modes in serious games: Multi-player and single-player. The multi-player 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 serious games offer the two play modes and others are limited to only one play mode. To be more concrete, we present in Table I some examples of serious games with their application fields and targeted population.

After a brief discussion about the definition of serious games and their application, we present, in the following, the motivations that conducted to write this paper.

Despite the interest of serious games, their use is still limited in learning processes. In fact, many teachers refuse to adopt recent teaching methods especially serious games because there is not information or tools allowing to predict the results of adopting a serious game in a particular learning process. This kind of information is generally provided by evaluation and simulation works. In reality, the integration of a serious game in the learning process does not necessarily guarantee good outcomes. In fact, when the chosen game is not adapted to a specific learning environment, this it can cause negative emotions among the learners such as stress, boredom or abort. Hence, the learning process will be failed as well as a huge waste of time and money. So, the choice of a serious game must be carefully studied before its integration in a course by considering the most important features of the learning environment. In this context, we propose a serious game simulator allowing teachers to predict the impact of adopting a serious game in a particular learning process. The simulator is based on agent technology which is adapted to represent several characteristics of players such as autonomy, reasoning, decision making, perception and action. It receives as input several characteristics of the game and the players, and thanks to specific functions, it generates a report to predict the results of the learning environment and emotional characteristics of learners-players. This solution is supposed to encourage the use of serious games by giving an expectation of its effect on a learning environment.

This paper will be organized as follows. In Section II, we

TABLE I
EXAMPLES OF SERIOUS GAMES [6]

| Serious Game | Application field | Targeted population |
|---|---|---|
| GoodGame Empire | Defense/Military | All public |
| Arcademic Skill Builders | Education/Pedagogy | Students of 3-7 years of age |
| Terrabilis | Ecology | People of 8-35 years of age |
| 3D VIRTUAL OPERATING ROOM | Healthcare | Professionals and students |
| 100ml Dash | Advertising | All public |
| 8th wonderland | Politics | People of 17-60 years of age |
| 3D Rseaux | Business | Professionals and students |
| 10 Minute Solution | Sport | All public |

position the reader in the context by summarizing most of the existing works on serious games evaluation and simulation. In Section III, we describe the proposed model. In Section IV, we present the implementation of the proposed simulator. In Section V, we illustrate an experimentation on the serious game "CodeCombat" to verify the reliability of our tool and we compare the experimentation results with the simulation results. Finally, we conclude this paper by discussing our findings and initiating our future work.

## II. STATE OF THE ART

In this section, we start by defining the followed research methodology to carry out a literature review of serious games evaluation and simulation. Next, we summarize the most important works found in this scope.

### A. Research Methodology

The research works are more and more numerous and scattered, therefore the realization of a state of the art in any area is a difficult task. In addition, we must note that a missing or inadequate state of the art may impact the project negatively. For these reasons, we began our work by carrying out a state of the art which followed a known and validated methodology entitled "Systematic Literature Review (SLR)". A SLR allows to identify, to evaluate and to integrate the findings of most of the relevant research papers by addressing one or more research questions [7]. A SLR should comprise essentially four steps: the formulation of research questions, the identification of search terms, the launch of automatic research in different research bases and finally the formulation of inclusion and exclusion criteria. In the following points, we describe the different steps having to be carried out in a SLR.

1) **Research questions formulation:** This step consists in formulating clear and precise research questions. In this
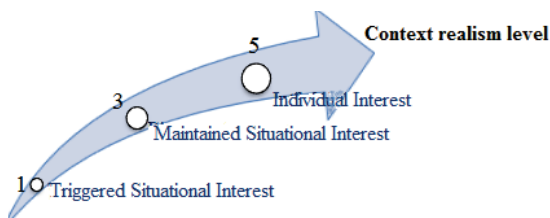


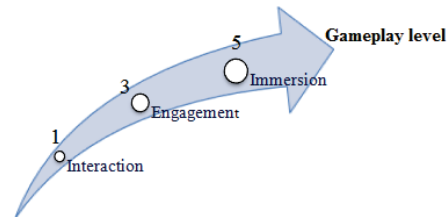Fig. 1 Evolution of Interest Degree Depending on the Context Realism



Fig. 2 Evolution of Immersion Degree Depending on the Gameplay
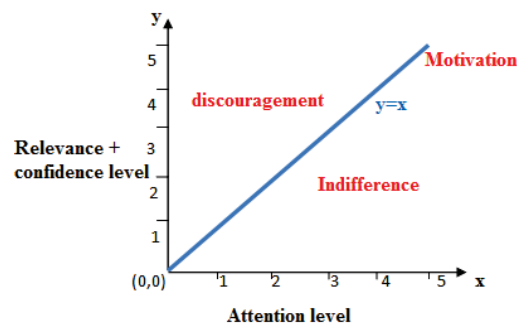


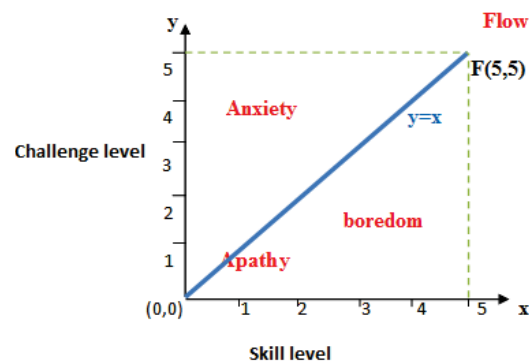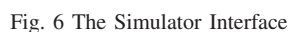Fig. 3 Relation between the Attention Level and the Relevance and Confidence Level



Fig. 4 Relation between the Skill Level and the Challenge Level [19]

Fig. 5 The Proposed Model

TABLE II
MODELING FEATURES DESCRIPTION

| Feature name | Description |
|---|---|
| Game challenge | The difficulties and the problems proposed by the game |
| Context realism | The ability of the game scenarios to be useful in real life |
| Gameplay | The ability of the game to be played |
| Game attention | The presentation style of the information in game |
| Game relevance and confidence | The importance and the ease of learning |
| Game feedback | The perception of actions consequences |
| Player skill | The player aptitudes and abilities |
| Flow degree | The pleasure level while playing serious games |
| Immersion degree | The feeling of being involved in a game session |
| Motivation degree | The enjoyment level while playing serious games |
| Interest degree | The feeling of giving curiosity and concern to the game content and to discover more about it |



Fig. 6 The Simulator Interface

work, the addressed research question is: How to predict the consequences of integrating a serious game in a learning process?

2) **Search terms identification:** This step is focused on relevant keywords allowing to find works related to the considered problem. In this work, the search terms were (serious game OR learning game OR educational game OR games-based learning). In addition, other search terms used for the impacts and effects of serious games were (evaluation OR emotion OR simulation OR assessment OR motivation OR engagement OR Flow).

3) **Research Databases selection:** The review followed a predefined procedure consisting in searching the previously identified terms in the most popular databases such as Scholar Google, Elsevier, ACM Computing Reviews and Semantic Scholar.
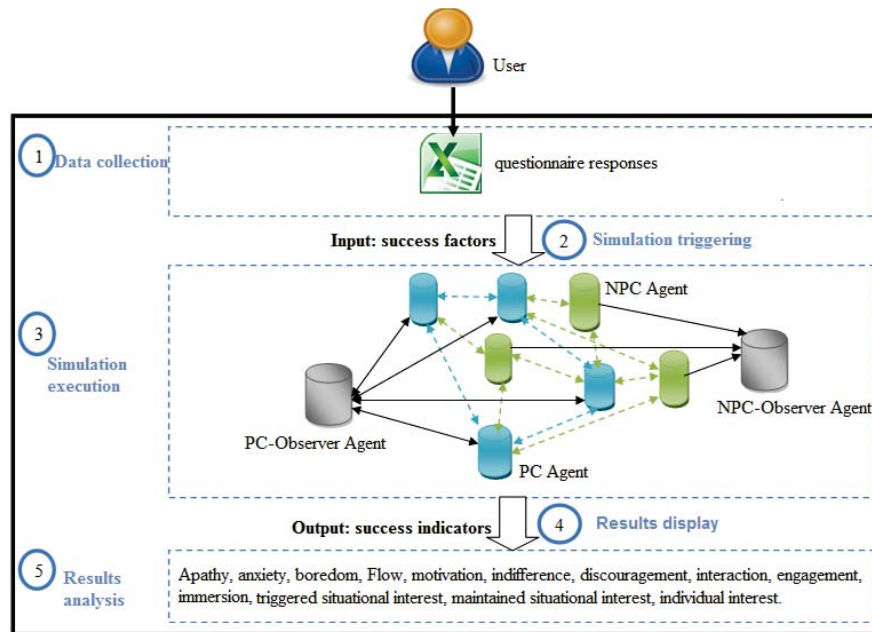
Fig. 7 The Simulation Process

4) **Inclusion and exclusion criteria formulation:** This step allows to retain the papers that respect inclusion criteria and to eliminate other papers that obey exclusion criteria. In this work, we start by identifying these criteria. Then, we include the papers that present a model, technique or method to evaluate or simulate serious games, explain the evaluation/simulation process of serious games or study the player emotional state during a game session.

The carried out SLR has shown an interest of several works to evaluate serious game based environments and to deal with the players feedbacks during a game session. In the next part, we report the contributions proposed by these works.

*B. Related Work*

Our work is performed in the context of a rich literature focused on serious games evaluation in learning processes, NPC (Non-Player Character) simulation in serious games and the most important simulators found in this scope. We present in the following these works, then we discuss them in order to propose our solution.

- **NPC modeling and simulation:** In this context, Ochs et al. [8] and Sehaba [9] developed tools that model and simulate the non-player behavior in video games and/or serious games. Their works aimed to improve the NPC credibility and to increase consequently the feeling of immersion and pleasure among players during a game session.
- **Serious games evaluation:** To evaluate serious games, different criteria were proposed. For instance, Derbali [10] has focused on motivation evaluation basing on the motivational model ARCS (Attention, Relevance, Confidence and Satisfaction) since it represents a key factor of an efficient learning. This research aimed to fill the lack of motivation evaluation in serious games. In addition, Kiili and al. [11] have proposed a Flow framework describing the dimensions of an optimal experience designated by "Flow" in educational games. In order to assess the usefulness of the framework aspects, they have developed a questionnaire in relation to the experience of students in "REALGAME" which is a collaborative game of business simulation. Furthermore, the authors of the research work referenced by [12] have presented a feedback on a serious game experimentation used to teach information systems which is "INNOV8". They have evaluated the use of this game focusing on evaluation learning aspect and the feedbacks of teachers and students were positive.
- **Existing simulators:** In this scope, we cite the "Simul8" tool [13] representing a powerful and intuitive simulation software that anyone can use to get fast results. It allows to improve processes, to increase efficiency and to reduce costs. Moreover, the "TARDIS" project [14] represents a simulation platform for job interview. It consists in realizing a serious game to simulate a job interview in which the recruiter is a virtual agent able to interpret and to react to candidate attitude and emotions during the interview. In addition, we cite "OSSE" [15] which it is another simulation tool that allows to simulate the static and dynamic components of a virtual socio-emotional character.

Ochs et al. [8] and Sehaba [9] have allowed us to have an overall view on the way to model emotions, but their

objectives are different to ours. Indeed, we hope to simulate a learning environment based on a serious game by taking into account the learner emotional state as well as different features representing the game.

The author [10] has not considered the dependencies that may exist between the four dimensions of the ARCS model. Moreover, he has not talked about other emotions that result from the use of serious games like immersion, the feeling of interest, boredom and anxiety. Besides, the work referenced by [11] is limited to Flow experience. Also, Chourabi et al. [12] focused on the learning dimension and the assessment of learning objectives treated by the serious game without taking into account other important dimensions in the evaluation of their use like the player emotional state.

Each one of the cited simulators presents its own limits. In fact, the "Simul8" simulator is an expensive tool, not accessible for free and especially it is not intended to simulate serious games. Concerning the "Tardis" simulation platform, it looks interesting. However, it remains limited since it simulates and detects the emotions felt by candidates during a job interview which it is a particular activity. As regards the "OSSE" simulator, despite it simulates the behavior, the personality, the emotions and the social relationships of a virtual socio-emotional agent, it does not allow to simulate the player emotions during his activity.

All these researches present interesting results focusing on serious games evaluation and NPC simulation. However, most of them are applicable after the serious game use and there is no work that allows to give a perceptibility on learning effects using serious games. 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 is supposed to allow teachers to study the impact of a serious game (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 serious game environments which will be described in the following section.

## III. PROPOSED MODEL

Since our original objective consists in predicting the success of a serious game based learning, the proposed model must be based on meaningful success features. For this aim, we benefited from the previously described works to identify relevant success features of the studied environments including the serious game as well as the players. In what follows, we present the selected features to represent a serious game environment, then we describe the dependencies between them as well as the proposed model.

### A. Modeling Features

Our contribution is inspired by studies focused on criteria used to evaluate a serious game. According to related work, there are factors that affect the success of a learning environment based on serious games such as the challenge, the feedback, the context realism, the relevance and the confidence, the gameplay, the attention and the skill. Some
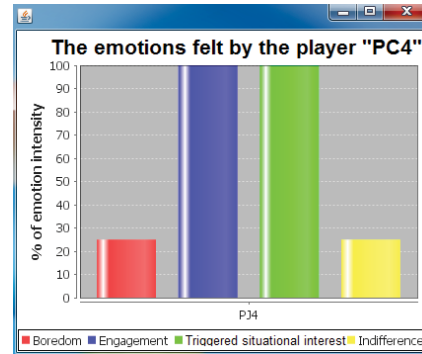
Fig. 8 Emotions Felt by the Player "PC4"

of relationships between these features produce the aspects which determine or express this success like Flow degree, interest degree, immersion degree and motivation degree. The definition of each aspect is described in Table II.

We describe in the following the functions that link success factors that represent the simulator input as well as the success indicators that appear as simulator output.

- **Context realism:** This aspect means the ability of the serious game to describe real situations and concrete scenarios that can be applicable in real life. Basing on the four-phase model of interest development proposed by Hidi and Renninger [16], we distinguish three different interest degrees: The triggered situational interest (what can provide to me the fact to learn through a serious game), the maintained situational interest (what can offer serious game to my personal training) and the individual interest (interest for a particular academic discipline). we have noted first that the feeling of interest is strongly linked to the context realism. Then, we have proposed a function that contained a scale of five points as indicated in Fig. 1. In reality, when the level of this aspect increases, the interest becomes more and more intense. 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 cannot achieve the individual interest that if the provided value is equal to the maximum value 5.

- **Gameplay level:** This aspect presents a key factor to keep the player engaged/immersed in the virtual world of the game. It expresses the ability of the game to be played and it includes several factors like sound elements, animations, colors and graphical quality [17]. At the beginning of the game, an interaction between the player and the game occurs. This interaction takes place during the discovery of the game (while reading the rules). As shown in Fig. 2, when the intensity of this feeling increases, the player attains the engagement state. This state happens when the player is actively involved in
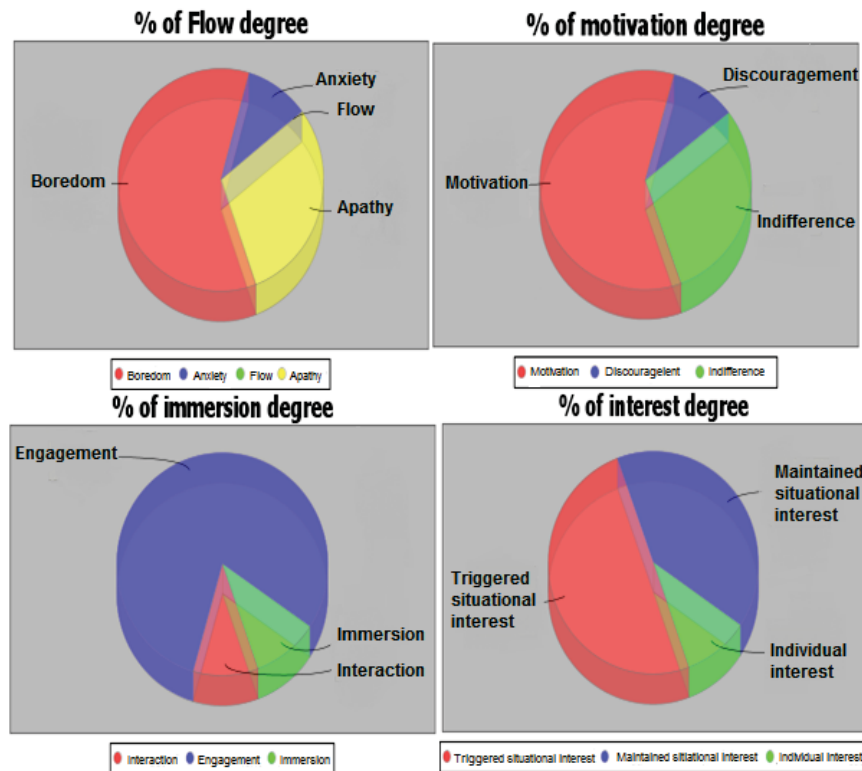
Fig. 9 Percentages of Global Emotions

the resolution of a particular problem. During a game session, the player can feel immersed in the realization of an activity. It involves a passive act and it reduces the concern of self and the sense of time. This state is therefore deeper and more intense than the engagement state.

- **Game attention and game relevance and confidence:** Basing on the motivational model ARCS [18], we extracted a strong relationship between the attention level (the fact to attract the player attention on the presentation style of the information in game) and the relevance and confidence level (the perception of the importance and the ease of learning). In fact, if the player believes that the level of relevance and confidence is high and that the attention level is low, he feels discouraged. Contrarily, a relevance and a confidence perceived as lower than the attention level will be a source of indifference as illustrated by Fig. 3. The feeling of motivation is occurred when there is a perception of a balance between the attention level and the relevance and confidence level.

- **Game challenge and player skill:** The most influential construct used to explain subjective experience while playing games is Flow theory [19]. Cskszentmihlyi developed the notion of Flow defined by: *"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"* [19]. The Flow state depends on the actor skill 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 Fig. 4. 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 a neutral emotion that occurs when the values of skill level and challenge level are equal but they are not maximal.

All these features are summarized in Table III.

*B. Detailed Description of the Model*

Basing on the previously described features, as well as the relations between them, we proposed the success-oriented model of serious game-based environments shown in Fig. 5. In fact, in a multi-player serious game environment, the players control, through their keyboard and their mouse, their PC (Player Character) within the system. The PC evolves in the game environment including entities and objects populating it and interacts with other PC and NPC of the game(Non-Player Character is a character controlled by the game artificial intelligence). The player must detect the changes produced in the environment, then he acts by taking into account his characteristics (his skill level), those of other players as well as the characteristics of the game consisting of: the challenge

TABLE III
MODELING FEATURES IN SERIOUS GAMES

| Success factors | Success indicators |
|---|---|
| - Context realism | - Interest degree (triggered situational interest, maintained situational interest, individual interest) [16] |
| - Gameplay | -Immersion degree (interaction, engagement, immersion) |
| -Game attention | -Motivation degree (indifference, discouragement, motivation) [18] |
| -Game relevance and confidence | |
| -Game challenge | - Flow degree (boredom, anxiety, apathy, Flow) [19] |
| -Player skill | |

TABLE IV
COMPARATIVE TABLE OF SIMULATOR RESULTS AND REAL RESULTS

| Simulator results | Real results |
|---|---|
| 0% of Flow | 0% of Flow |
| 60% of boredom | 57.2% of boredom |
| 10% of anxiety | 7.1% of anxiety |
| 30% of apathy | 35.7% of apathy |
| 60% of motivation | 57.2% of motivation |
| 10% of discouragement | 7.1% of discouragement |
| 30% of indifference | 35.7% of indifference |
| 50% of triggered situationel interest | 57.2% of triggered situationel interest |
| 40%of maintained situationel interest | 35.7% of maintained situationel interest |
| 10% of individual interest | 7.1% of individual interest |
| 10% of interaction | 7.1% of interaction |
| 80% of engagement | 85.8% of engagement |
| 10% of immersion | 7.1% of immersion |

level, the gameplay level, the relevance and confidence level, the feedback level, the attention level and the context realism level. The PC or the NPC can be represented by an agent who is able to perceive other players states and to make decisions basing on his information in order to adapt his characteristics to the considered game environment.

## IV. SIMULATION

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.

### A. Simulator Implementation

The proposed model can be represented by a MAS (Multi-Agent System). A MAS is a set of intelligent agents interacting with each other, situated in a common environment and able to control their own behavior according to their own goals [20]. In this work, our simulator represents a serious game environment consisting in different reactive agents interacting with a game since they just have reflexes without maintaining any internal state. The proposed tool allows to simulate the multi-player serious games as well as the single-player serious games because it is composed by human players and non-human players. In fact, we have implemented essentially four 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 other agents states in order to update his state and then act on the game environment.

- **Non-player agent:** This agent represents the non-player character of the game that is characterized by a ranking which it is sent to the NPC observer agent to inform it about his skill level.

- **PC observer agent:** This agent allows to calculate the average skills of all player agents and to inform them 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 skills.

### B. Simulation Process

As shown in Fig. 7, the main steps of the simulation process are: Data collection, simulation triggering, simulation execution, displaying results and result analysis. In the following, we detail each step of this process:

1) **Data collection:** This first step consists in collecting data about the game and the players through a questionnaire. This questionnaire is intended, essentially, to teachers who wish studying and simulating a serious game before its integration in the learning process of a particular course. The teacher must therefore express his degree of agreement or disagreement on each item in order to quantify the characteristics of the considered environment consisting of: The challenge level, the relevance and confidence level, the gameplay level, the context realism level, the attention level and the feedback level.

2) **Simulation triggering:** 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 they 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 degree to determine the NPC skill level as illustrated by Fig. 6.

3) **Simulation execution:** 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, their values are periodically updated. As a result, the simulator gives the emotions intensities felt by each player as well as a report of global emotions.

4) **Results display:** This step consists in displaying the generated results in a graphical form.

5) **Results analysis:** This step aims to interpret the obtained results.

### C. 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 serious game "CodeCombat" which will be described in the following section. The simulator gives two forms of results: The first displays the emotions felt by each player as shown in Fig. 8 and the second shows a report of the global emotions as illustrated by Fig. 9. For example, Fig.8 depicts the emotion intensities as percentages. This figure shows that the player identified by "PC4" feels 25% of boredom, 100% of engagement, 100% of triggered situational interest and 25% of indifference. These emotions represent respectively the flow degree, the immersion degree, the interest degree and the motivation degree. Fig. 9 summarizes major emotions in the environment by showing global emotional rates.

As shown in Fig. 9, the results showed that 60% of players have felt boredom, 30% expressed apathy and 10% have felt anxiety. In other words, more than half of students think that the game is boring because the proposed challenge level is lower than their skills level. About the interest degree, we found that 50% of learners have felt triggered situational interest, 40% have felt maintained situational interest and 10% expressed individual interest. Thus, a minority of students found that the game is very interesting in terms of content and academic discipline. Besides, the report indicated that 60% of players have felt motivation, 30% expressed indifference and 10% have felt discouragement. This result proved that the majority of players have enjoyed the game experience. Moreover, the study showed that 10% of learners have felt interaction, 80% have felt engagement and 10% expressed immersion, therefore a minority has felt strongly involved in the virtual world of the serious game.

## V. Experimentation

This step aims to test the proposed simulator and to verify the reliability of the provided emotional predictions by comparing them to real feedbacks. This experimentation is carried out in the context of a programming course in an engineering school. It is based on the serious game "CodeCombat" [21] which is a multi-player game designed for learning programming languages. Given the purpose of this experimentation work, it was 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, a specially designed questionnaire was proposed to all the participants in order to report the emotions felt by each player and to verify their conformity to results provided by simulator. To perform the simulation step, the responsible teacher of the previously described learning session must answer to the questionnaire described in Section IV to give the game features and launch the simulation using the simulator interface.

To facilitate the comparison between the results obtained from the real learning scenario and the simulation process, we summarize them in Table IV.

As shown in Table IV, the proposed simulator gave results close to the reality, which is considered as a positive outcome. Indeed, our study showed that the game has created boredom (57.2%). This finding is explained by the fact that the players skill level was higher than the proposed challenge level. However, we noted that the use of a serious game to learn how to code was, for the majority of learners, a good experience (57.2% have felt motivation): The student has discovered a new device of learning more attractive and more motivating than the classical courses. We noted also that the rate of individual interest is low (7.1%) which means that the game does not offer important and interesting knowledge to learn coding. So, the game must propose more realistic scenarios and situations which can be applicable in real life. Concerning the immersion degree, we found that 85.8% of learners have felt engaged which proved that its game dimension, including music, graphics, conviviality and ergonomics, is well designed and attracts the players attention.

At the end of this section, we conclude that this game is not adapted for this kind of learners. It will be better to increase the difficulty degree of the game or to change it completely. We must note that there are also other features which they have an impact on simulation results like the game learning objectives and the player ability to concentrate.

## VI. Conclusion and Future Work

In this paper, we have presented the results of investigations on the main challenges of the serious games integration in learning processes. For this purpose, we simulated, in this study, the integration of serious games in learning processes. In fact, we proposed a model based on emotional states of learners and different features of a game environment in order to analyze and simulate the use of a serious game before its adoption in the learning process. Then, we have developed a multi-agent based simulator. After that, we studied the playing experiences of the serious game "CodeCombat". The results showed that, despite the absence of pleasure, the

perceptions of this game were positive. The proposed tool is intended to teachers wishing to integrate a serious game in their classical courses in order to motivate students and to make the knowledge acquisition more attractive and more efficient. It allows them to study the adequacy of the serious game to the skill level of their students. We estimate that the proposed tool will encourage the passage from traditional to modern learning methods.

Future work in this area could be carried out to extend the proposed simulator by adding other features and especially the learning aspect. It would also be interesting to consider some of player personality aspects since they have an impact on the type and the intensity of the detected emotion. For example, the Big Five personality traits are the best accepted and most commonly used model of personality in academic psychology. This model is based on the five following factors: openness to experience (characterized by imagination, unusual ideas, curiosity and creativity), conscientiousness (includes high levels of organization with goal-directed behaviors), extraversion (characterized by excitability, sociability, energy and positive emotions), agreeableness (includes attributes such as trust, altruism, kindness and other prosocial behaviors) and neuroticism (characterized by sadness, anger, depression and emotional instability) [22]. Furthermore, one of our future aims is to validate the simulator in different game contexts with other student populations.

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