Agent Supported Serious Game Environment

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Abstract—This study proposes and applies a novel concept for an AI enhanced serious game collaborative environment as a supplementary learning tool in tertiary education. It is based on previous research that investigated pedagogical agents for a serious game in the OpenSim environment. The proposed AI features to support the serious game are the following: a) a pedagogical game agent, b) non-playing characters, c) chat bots, and d) a game interface called "Progress Map". This study aims to explore whether the utilization of AI features in game based collaborative learning in a tertiary education course can positively affect students' attitudes towards the course and educational games, students' game performance, as well as the students' perception of their learning environment. Summarizing, even though the intelligent game environment does not affect students' attitudes, neither towards the course nor towards the educational games, it has a positive impact on the performance of the teams and so it can be considered useful in collaborative game based learning. Moreover, the intelligent game environment improves the cohesiveness in the classroom after the completion of the game activity in terms of helping, supporting, and becoming connected to each-other.

Index Terms—Adaptive and intelligent educational systems, educational games, collaborative learning tools, virtual and augmented reality, information interfaces and representation (HCI)

1 Introduction

Game based learning and collaborative web-based learning environments have become very popular across all levels of education (i.e., from primary to higher education). Continuously evolving computer technology renders it essential more than ever to support students of all ages in web based educational environments. Pedagogical agents (PA) could assist in this direction. Most of the definitions on PAs include or imply the concept of intelligence, thereby indicating the close relationship with Artificial Intelligence (AI). PAs are intelligent agents that support educational procedures taking place in synchronous learning environments aiming to achieve better learning [1]. According to [2], PAs are animated lifelike autonomous characters that cohabit learning environments with students to create rich, face-to-face learning interactions and aim to engage and motivate students in their learning process. Aguilar et al. [3] define a PA as an intelligent agent who makes decisions about how to maximize the learning of a student and observes an environment in which the student in his learning process, is located [3]. According to the goal they pursue, PAs can be classified as: tutors [4], [5], mentors, coaches, motivators, assistants [6], learning companions-co-learners [7], [8], [9], collaborators [10], competitors [11] and trouble makers [12]. When PAs are used in the context of Computer Supported Collaborative Learning (CSCL) they can be considered as a collaborative learning technique. Churchill et al. [13] define a Collaborative Virtual Environment (CVE) as a computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents, or with virtual objects. Agents in collaborative virtual environments could be represented from 3D human-like avatars to 2D interfaces that provide feedback in the form of hint. The most common roles that an agent can serve [14], [15] in a collaborative virtual environment are: a) monitoring the collaborative learning process, b) providing feedback and guidance to activate interaction and collaboration among participants, c) providing information on the current state of a learner's interaction and d) giving advice on the learning process according to the process and strategy of collaborative learning.

On the other hand, game developers also employ AI techniques for various reasons [16]. Umarov et al. [17], while regarding believability and effectiveness as the two main design challenges with respect to agent's behavior in 3D games, recognize that there are also other features that make agents "fun to play with". In general, the use of AI in education has many goals among others to match the needs of individual students and understand how human emotions influences individual learning differences [18]. AI models used in education reason about domain knowledge follow a student's reasoning about that knowledge, engage in discussions, and provide sophisticated feedback. Intelligent instructional software augments a system's teaching ability by storing teaching methods and processes such as strategies, feedback, and assessment [18]. Past research indicates that the types of the learning environment associates with the nature of students' learning [19]. In modern education, learning environments and serious games environments find application in virtual worlds. Eseryel et al. [20] identify interactivity as "one of the most salient characteristics to which educational game designers should attend". In order to deliver an appealing game learning environment it is important to identify the game features that would motivate students to play and have fun. Keller's ARCS model [21] explicates learners' motivation through four concepts: a) Attention, b) Relevance, c) Confidence, and

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d) Satisfaction. Chang and Zhan found that motivation positively influences attitude toward online games [22]. With respect to serious games, instructional designers aim to motivate students to learn; They identify the followings motivation features that such games have to fulfill: challenge, rules, control, curiosity, fantasy, dynamic visuals, interaction, risk, feedback, competition, game story, mystery, sensory stimuli [23], [24], [25], [26], [27].

Furthermore, when an agent is designed for a collaborative serious game, additional requirements have to be fulfilled in order to facilitate students' collaboration. Game Based Collaborative Learning (GBCL) involves interaction of two or more learners within a game-based learning environment designed and/or used with the intention to develop learning in a collaborative manner [28]. According to [29] agents in teams are expected to achieve the following improvements: a) reduce time for human teams to make a decision, b) allow teams to consider a broader range of alternatives, c) enable teams to flexibly manage contingencies (replan, repair), d) reduce individual and team errors and e) increase overall team performance. In general, an agent facilitates teamwork between humans involved in a group task by aiding communication, coordination, and focus of attention [30]. An additional parameter which needs to be considered is the technology used in the implementation of the educational game. There are several researchers that indicate the negative aspects of using virtual environments for learning and the difficulties that students face [31], [32], such as the technical abilities needed to act and to navigate on them. The use of AI techniques might contribute to address this difficulties by providing additional help during the learning process in virtual environments. Moreover, the integration of AI techniques in 3D game based learning seems like an additional tool that could lead to more efficient environments and hence result in better learning. Although the employment of PAs intents to facilitate learner's motivation and learning outcomes, research on the motivational and learning effects of PAs is scarce [33]. Similarly, literature research review of [34] regarding the pedagogical benefits of character enhanced learning systems summarizes that evidence is "rather scattered and contradictory"; [34] interprets this as a reflection of the field's complexity and points out the need of long-term real use of these systems.

Even though much research has been done in the fields of serious games, PAs, virtual worlds and computer supported collaborative learning per se, very little has been done considering how PAs affect students' collaboration, motivation, enjoyment or performance in an environment that combines all these parameters, namely a 3D collaborative educational game. Recent research indicates the significant potential of intelligent game-based learning environments for learning both in and out of the classroom [35]. Taking the field's complexity into account, this work will try to overcome this research gap by introducing an integrated PA environment. Moreover, this study aims to answer whether the use of AI in collaborative serious games is effective in terms of improving students' attitudes towards the course and educational games, improving the classroom environment and achieving better team performance by enhancing students' collaborative interactions through a motivational learning environment. In more detail, this study aims to investigate the efficacy of AI features in virtual game environment by answering the following research questions:

RQ1: In what terms does an agent supported serious game environment affect student attitudes towards the course and games?

RQ2: In what terms does an agent supported game environment affect the classroom environment?

RQ3: What is the impact of the support provided by a pedagogical game agent (PGA) on the performance of a team?

This paper is organized as follows: Section 2 introduces the design proposal for the agent supported serious game environment. Section 3 presents the evaluation carried out. Section 4 reports the results derived from the evaluation. Section 5 discusses the outcomes. Section 6 presents the limitations that have to be considered. Conclusions and future work are drawn in Section 7.

2 Design Proposal: Agent Supported Serious Game Environment

The architectural design proposed by this study introduces an agent supported serious game environment which aims to enhance collaborative educational games and facilitate the educational procedure with the aid of different kinds of PAs and intelligent interfaces. The agents and the additional intelligent interface were designed to accomplish specific pedagogical roles, namely: motivator, navigator, collaboration assistant, game facilitator and to transform the game space into an intelligent virtual learning environment. To address these requirements, based on a pilot research experiment [36], a controlled study was conducted.

2.1 The Game Scenario

The proposed agent supported game environment was based and applied on an already existing immersive collaborative game, which is referred to as OSgame [37], [38]. This study intentionally utilized an immersive environment due to following reasons: a) to promote the collaboration between students through a 3D representation of the collaborative game, as suggested by [39], and b) to enhance students' motivation and interest; in such immersive environments students are fully engaged and immerged in them, fact which, according to [18], "provides a distinctive 'believability' advantage over non-immersive environments". Moreover, the OSgame is a three dimensional collaborative knowledge game implemented in the OpenSim virtual world [40] and it was based on a framework that focused on the design of game based learning applications through collaborative educational virtual environments [41], [42]. In the OpenSim environment users are represented by avatars; for their interaction, OpenSim provides multiple communication channels, such as open text chat called local chat, private personal and team text chat, Voice over IP (VoIP) chat and non-verbal communication through avatar gestures. When the OSgame session starts (Fig. 1), the players begin their virtual exploration of the game environment, trying to discover the virtual objects containing questions.

To each session, fifteen multiple-choice questions, based on the undergraduate course, "Multimedia Systems", interspersed in virtual objects must be found within a 30 minute

Fig. 1. Snapshot from the OSgame: Students at the game lobby waiting for the game start.

time frame. Game points are awarded for each question that is answered correctly by a team. Players can ask for help by clicking the "Help" button, which provides an extra help text, while at the same time there is a point penalty against the asking team. Every time a player opens a question, his/her team is charged with some points. Players get the appropriate feedback which informs them of the result for their answer. The game ends when: a) one team answers all available questions b) the predefined game timer runs out, or if c) all teams answer all the questions. The team with the highest score is the winner of the game.

Considerations for the design choice were derived both from the bibliographical research and the previous research results [36]. The adjustments relate to the following: a) the OSgame activity scenario has been redesigned to take place as a tournament with a duration of two and a half months, instead of an one-time intervention, and b) an integrated intelligent game environment was designed instead of a single agent support by adding new intelligent features and different kinds of agent support. More specifically, to enhance OSgame's intelligence the following features were implemented: a) a *pedagogical game agent* called "Aristotelis", b) *non-playing characters* (NPCs) as tour guides for the virtual game environment, c) *autonomous pedagogical chat bots* and d) a *game interface tool* called "Game Progress Map" for monitoring team progress during the game. The decision to use different kinds of agent support was adopted from [34], who proposed different pedagogical roles and strategies of pedagogical characters as critical factors when aiming to develop successful character enhanced systems.

2.2 The Pedagogical Design Model

Affect seems to play an increasingly important role in game-based learning environments [35]. On the other hand, learners' positive attitudes towards the course and the games are important in this research study and provide "at the outset a strong motivational state" to support learning [43]. For the PA mechanism it was decided to employ strategies based on the learning theories of Keller's ARCS model [21] in conjunction with our proposed agent model. More particularly, this study uses the ARCS model for the analysis and the design of the motivational strategies in order to offer an appealing agent supported learning environment that might positively affect students' attitudes.

2.2.1 The ARCS Model

The ARCS model explains motivation through a four-factor theory [21]. Moreover, the ARCS model is a motivational design process that includes concepts and theories that are clustered into four categories [44]. These four factors are: a) attention - gaining and sustaining attention to the instructional content, b) relevance - relating to learning objectives and future use of learning, c) confidence - confidence in learning and accomplishment, and d) satisfaction – promoting the potential for learning satisfaction. Keller's ARCS motivational design process consists of ten steps, from knowing and identifying the elements of human motivation to evaluation and modification [44]. The ARCS systematic design process can be applied to designing educational learning environment, such as the proposed intelligent game environment. In the current study only the first nine steps of the ARCS design process leading to the evaluation step, were applied. As this study focuses on the efficacy of the whole AI educational game environment, the evaluation, which is the last step of the ARCS process, was decided to be adjusted to our research questions, investigating: a) students' attitude towards the course and games, b) the effect of the AI enhanced game on the classroom environment and c) the students' performance in the game.

2.2.2 The ARCS Model Extension

The ARCS model was slightly modified in order to support motivation in case of collaborative learning settings and meet the requirements of an AI enhanced collaborative educational game environment. The *collaboration* factor was added to provide strategies on motivating students' collaborative interactions. The extended agent model is presented in Table 1. In detail, the first two columns correspond to the original ARCS motivational model while the rest of the columns and the last row correspond to the agent model that has been extended by adding the further characteristic of collaboration in order to support CSCL in serious collaborative games. Additionally, the developed model provides strategies on stimulating and retaining each motivational factor though agents and/or intelligent interfaces (Table 1, columns 3 and 4). In detail, the PGA maintains the *attention*, *relevance*, *personal responsibility*, *satisfaction* and *collaboration* factors. Furthermore, the *success expectations* are intent to be retained by the NPCs, chat bots and the progress map, while NPCs aim also to retain the *collaboration* factor.

2.3 The System Architecture

This study proposes an autonomous agent mechanism that utilizes different data sources. Fig. 2 illustrates the architecture of the agent supported game environment and the interactions taking place between agents, students and the OSgame. In detail, the real time data input for the agent-support mechanism derived from three event sources: a) *Serious game's events*: events derived from the game scenario (i.e., scores, rules, restrictions) (Fig. 2, green colored arrows), b) *Events in the Virtual environment*: events derived from virtual objects (Fig. 2, blue colored arrows),

TABLE 1
Extended ARCS Model to Support 3D Collaborative Educational Games through PAs

ARCS Model for CSCL	Subcategories	Strategies of Game Agent Model	Agent's action
Attention	Stimulate Inquiry	Warn the player	PGA: Alerts for the termination of the game
		Encourage involvement	PGA: Checks whether a player is inactive (i.e. s/he has not moved) in specific time frame, and sends message.
	Maintain Attention	Reinforce Competition	PGA: Notifies of any change in teams' ranking by sending a message to all members of the related team (team message).
Relevance	Relate to Goals	Remind aim and rules according to player's actions	PGA: Draws attention to continuous incorrect responses and to assistance overuse
Confidence	Success Expectations	Provide help and awareness about the game	Chat bots, NPCs: provide personalized assistance Progress-Map: provides visualized information about teams' answered questions and their positions.
	Personal Responsibility	Personalized feedback	PGA: Warns player when s/he clicks more than three sequential times on same virtual object within three seconds.
Satisfaction	Rewarding Outcomes	Reward players	PGA: Displays game statistics and achievements Rewards teams when they achieve specific percentages of correct answers by sending a message to all members of the rewarded team (team message).
Collaboration	Motivate students' interactions	Trigger interaction between players	PGA and Chat bots: Encourage players individually to chat more with their team members (if they were inactive for a specific time)

and c) *Players'/avatars' events*: triggered by players' chat interactions (Fig. 2, red colored arrows).

The support mechanism provided by the agent (indicated with the black colored arrows in Fig. 2) falls into three categories: a) pedagogical/game guidance: guidance regarding the OSgame through messages to students' teams or to each student individually, b) game awareness: personalized help and instructions about the virtual environment and the OSgame rules through dialog with the autonomous chat bots, c) spatial guidance: a virtual tour of the premises and buildings of the game environment. From the AI perspective, all agents in the intelligent game environment are acting autonomously and just when necessary. Additionally, the AIML chat bots have the ability to communicate with the students. Each entity will be presented in detail in the following sections.

1. *The Pedagogical Game Agent*. The "Aristotelis" agent was integrated in the OSgame environment and was designed to operate as a PGA, entrusted with the role of motivator and collaboration assistant. According to the definitions of [2] and [45], the "Aristotelis" game agent can be considered both as pedagogical and motivational agent. The game agent can be classified in the category of Model-based reflex agents [46] and it partially handles the observable OSgame immersive environment. The current state of the game sessions is dynamically stored in the PGA

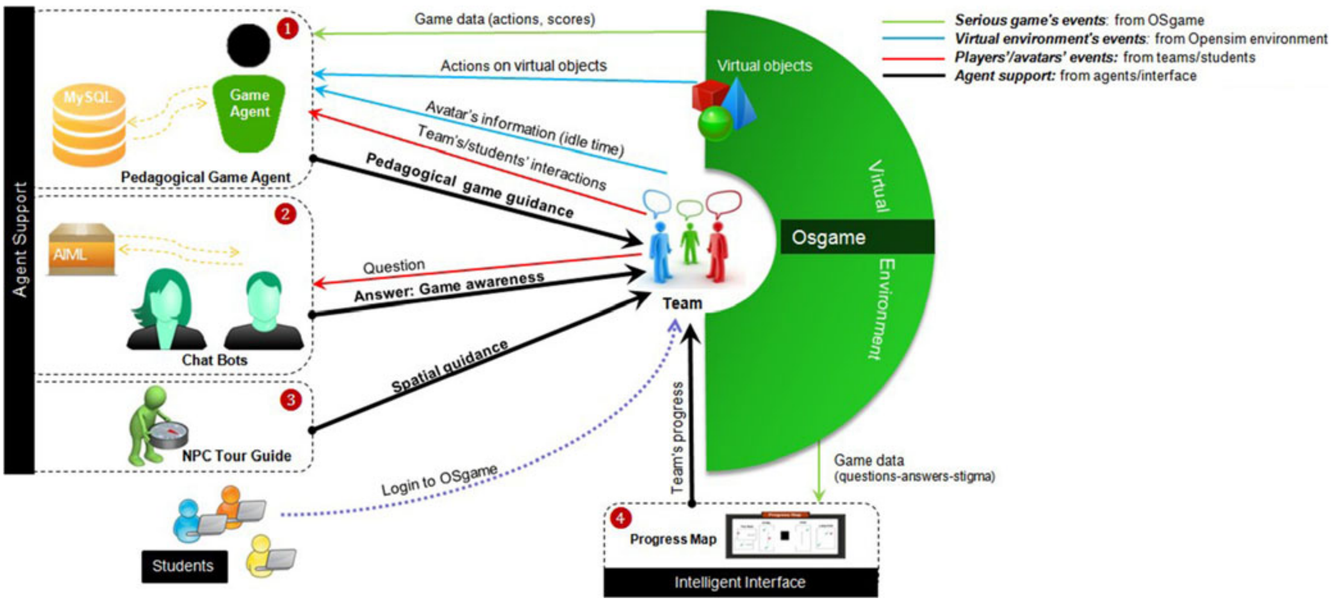

Fig. 2. The collaborative Agent Supported Serious Game Environment Architecture.

TABLE 2
Pedagogical Game Agent's Messages

Agent's Lexicon
• *That's the way to go on!*
• *Your team fell overall in the game. Guys you can do better!*
• *Try a little bit more and you can be the winner!*
• *Well done guys! Your team increased its difference from the second in rank team.*
• *The difference from the first team is increased. You can do better!*
• *Well done guys! The difference from the first team is declined.*
• *You answered many questions wrong! If you're not sure about an answer, try to collaborate more with your teammates because your team loses points.*
• *You have used many times the help option and this costs points to your team! If you are struggling in a question, you can always chat with your teammates and ask for help!*
• *Remember, your team needs your help to locate the hidden questions! Try to give more emphasis on exploring the world!*
• *Well done! You have answered correctly at 40 percent of the questions in the game! Keep at it and always remember to work with your teammates when you face difficulties. Good luck!*
• *The last minutes you have not contacted with your teammates through chat! Remember that you can chat with them to collaborate if it's hard to answer a question!*
• *Guys you have not used the group chat enough. Remember that you could get better performance if you collaborate during the game.*
• *Guys, the game will be over in 10 minutes! Keep at it and always remember to work with the rest of the team when it's hard to answer a question!*
• *Please avoid consecutive clicks on the object questions! Remember that every click is equivalent to opening the question. Thus your team loses points every time you click.*

structure. The agent was programmed with the OpenSimulator Scripting Language (OSSL), a special kind of code which is incorporated in scripts and can be placed in an object in the virtual space (LSL/OSSL [40], [47]). During an OSgame session the pedagogical game agent keeps track of the game progress and monitors the virtual environment through virtual objects. The PGA's main task is to provide appropriate pedagogical game assistance both on the individual level, to each student, and on the team level, to each team of students. More specifically, the pedagogical game agent: a) conjuncts received input from the virtual environment and students' actions during a session of the game and b) it chooses the appropriate message to communicate with the students by sending a personal or team message accordingly. In order to implement the PGA's model as presented in the extended ARCS Model (Table 1) a set of messages were composed forming the agent's lexicon (Table 2).

Fig. 3. LeeLoo and Andre AIML chat bots.

(a) (b)

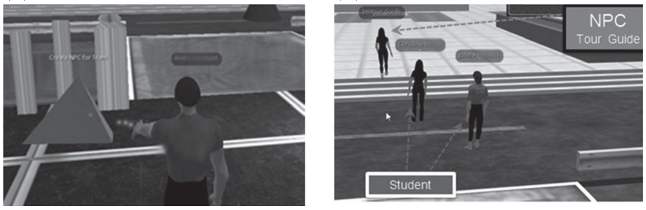

Fig. 4. (a) Automated NPC creation: user clicks on virtual object to generate a NPC. (b) The NPC avatar guides the students.

The "Aristotelis" game agent communicates with the students by using both local and private chat in the OpenSim environment. All messages sent by the PGA were saved in a MySQL database in order to keep track of its activity during the game. Furthermore, the PGA's behavior (e.g., limit for incorrect answers, percentage for rewarding teams) can be easily customized by the game administrator (i.e., the instructor) through the PGA's configuration web site. Additionally, there is an option to enable or disable the presence of the agent before the game session.

2. *AIML Chat Bots.* Two autonomous chat bots were created. They provide useful information about OSgame rules, the virtual game space and OpenSim functionality through dialog in natural language. The chat bots were represented as human looking avatars and had a name indicator over their head with their name followed by the word "*Assistant*". The two bots represented both genders; *LeeLoo Assistant* was female and *Andre Assistant* a male chat bot (Fig. 3). Students communicated with the chat bots using the private text chat, sent questions to them and got personalized assistance. For the implementation of the two pedagogical chat bots the AIML (Artificial Intelligence Markup Language) language [48] was used to create an appropriate AIML set for the OSgame both in the Greek and English language. Both bots had the same AIML set enabled.

3. *Non Playing Characters as Tour Guides.* Observations during the previous OSgame's study [36] have highlighted an important issue: students faced orientation difficulties in the virtual space, especially those that had no previous experience in 3D environments. Similarly, [2] stated that there are many chances for a student to get sidetracked when the virtual space is large and complicated. Because of the complexity and the large area of the virtual space the tour guide is necessary. Therefore, a NPC OSgame tour guide was designed to help students' orientation to demonstrate the position of game objects and finally provide them a better spatial understanding of the virtual game space. The NPC tour guide was implemented inside the OpenSim world with the OpenSimulator Scripting Language [49]. The virtual tours took place at the familiarization of the users with the virtual space (familiarization phase). At each virtual tour the non-playing character initially shortly introduced him/herself to the students and then prompted the students to follow him/her. After that, the NPC guide made a short tour of the virtual space (Fig. 4b) stopped

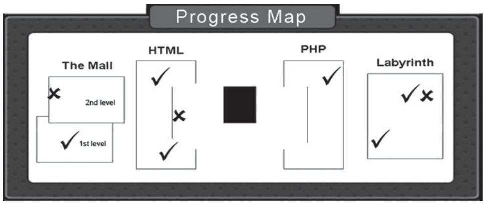

Fig. 5. Team's progress map interface.

at key locations and gave students textual explanations through the local chat. The non-playing character was automatically created when the user clicked on the "NPC generator" virtual object which contained the creation script. Students could "generate" their own non-playing tour guide character whenever they needed it (Fig. 4a).

4. *Progress-Map Interface.* The Progress-Map is used to provide a visual depiction of the achieved progress for each team on the floor plan of the virtual space. The Progress-Map operates collaboratively and was implemented as a head-up display (HUD) in OpenSim. Each team has its own progress map. Each member of the team can see the specific spots in the virtual space where found an answer as well if their answers were correct (depicted by the symbol ✓) or wrong (depicted by the symbol ✘) (Fig. 5).

3 Evaluation of the Agent Supported Serious Game Environment

At the design phase of the agent supported environment, the pedagogical ARCS model design principles were utilized to provide a motivational learning environment. However, since this study focuses on the efficacy of the whole AI educational game environment, it was decided to use different evaluation criteria than those proposed by the ARCS model. Specifically, the efficacy of the agent supported game environment was evaluated in terms of: a) students' attitude towards the course and games, b) the effectiveness and acceptance of the offered environment and c) the students' performance in the game.

3.1 Experimental Method

The evaluation of the implemented intelligent game environment was conducted in three phases: a) the pre-experimental, b) during the experiment and c) the post-experimental. Each phase consists of distinct information on goals, data collection methods and results, which are briefly presented in Table 3 (stripy cells indicate that no action was taken). Students' teams were randomly assigned to the control and the experimental group ensuring a similar average level of technological experience. In particular, the 14 students (Team 1-Team 6) who played the game without the intelligent interfaces (pedagogical game agent, chat bots, progress map) constitute the control group, while the remaining 20 students (Team 7-Team 15) constitute the experimental group in this research. Students were divided into dissimilar groups in terms of numbers because of: a) the odd number of leagues (five) and b) the limitation that each league game had to be played for all students participating with the same configuration (in the case at hand, with or without the agent). Thus, we opted for a greater number of students in the experimental group. The control group played the game without the intelligent intervention while the experimental group played with the intelligent intervention.

3.2 Participants

Forty-one undergraduate students (18 females, 43.9 percent and 23 males, 56.1 percent) initially enrolled to the OSgame activity as a mandatory part of the "Multimedia Systems" course. Out of the 41 that initially enrolled, ultimately, 34 students became active players and, as was mentioned above, 14 of them played the game without the intelligent interfaces thus constituting the control group, while the remaining 20 students became the experimental group. Out of the 34 students only 17.6 percent had previous experience in OpenSim platform, while 26.5 percent of them had previous experience in other virtual environments. However, students had a satisfactorily feeling of confidence in using 3D games (70.6 percent), with 47.1 percent of them declaring that they like games, 44.1 percent being neutral and only 8.8 percent of them were negatively inclined to computer games. It is worth mentioning that 14,7 percent of the students stated that they would need an extra assistance to act in a 3D game.

3.3 Materials

The materials used in this study consisted of following: a) one tutorial, "How to play the OSgame", b) the agent based game environment: one game agent, two chat bots, one NPC,

TABLE 3
Evaluation Plan

Phases		Actions (in/for OSgame)			Evaluation (data collection method)
Phase 1	Before OSgame (N=41)	Familiarization through NPCs (optional)			Pre-task questionnaire
		Form control and experimental groups			
Phase 2	During OSgame (N=34)	Collaboration among the members of each team to achieve game goal.			Database records Text chat log files
		Qualification	With [NPC] *Control Group (N=14)*	With Intelligent intervention [NPC, PGA, AIML Chat Bots, Progress Map] *Experimental Group (N=20)*	
		Finals	OSgame Tournament Finals without Intelligent intervention for all teams		
Phase 3	After OSgame (N=34)				Post-task questionnaire

TABLE 4
Reliability Statistics for Pre and Post Questionnaires

Variable	Cronbach's α	
	PRE	POST
Attitude Towards Course	.920	.900
Attitude Towards Games	.946	.929
What Is Happening in Classroom	.931	.911
Perceived Usefulness of the hypothetical use of agent	.895	.834
TOTAL	.952	.944

TABLE 5
Interpretation of the Team Formation Formula

Parameters	Description		Weight
LikeGames	Student likes Games	Likert [1 to 5]	1.3
LikeVLEs	Student likes VLEs		1.2
SelfEfficacyGames	Self-Efficacy in Games [54]		1.3
OSgameExp	Previous experience in OSgame	$Yes = 1$ $No = 0$	5
VLEsExp	Previous experience in VLEs		1

a "Progress map" interface, c) two online questionnaires: pre-test and post-test, d) log files of the chat interactions, e) database records, and g) a semi-structured interview. The data collected from the questionnaires are mainly quantitative and partly qualitative. Quantitative data sources also include database records. Qualitative data were collected through users' chat log files and semi-structured interview.

3.4 Measures

Measures used in this study were primarily adapted from previously validated instruments and in some cases modified to fit the context of the developed learning environment ([19], [50], [51], [52]). The data collected from the questionnaires rated students' attitude towards the course and serious games, students' perception about the hypothetical use of agents in educational settings and students' perception of their learning environment. Additionally, students belonging to the experimental group were asked to rate their experience with the agent supported game environment. The selected measures used a five-point Likert scale. Cronbach's alpha statistics was performed to test the reliability of the questionnaires (Table 4). The overall Cronbach's alpha for the pre- and post-task questionnaires revealed values of $\alpha = .952$ and $\alpha = .944$ respectively, showing a high internal consistency for the applied questionnaires. Internal consistency reliability for each variable range from .834 to .946.

The pre-task questionnaire comprised of 79 items, organized in four sections: a) attitude towards course [50] in terms of course-value, course-enjoyment and course-motivation, b) attitude towards games [50], in terms of game-value, game-enjoyment and game-motivation, c) students' perception about their classroom environment using three questionnaires of the *"What is Happening in this Class"* [19] instrument, namely, student cohesiveness, cooperation (referred to as Collaboration to suit the terms used in this study) and involvement and d) Perceived usefulness of the hypothetical existence of agent [51], i.e., how students perceive the usefulness of the hypothetical existence of an agent in general.

The post-task questionnaire for the control group comprised of 86 items; 79 of them were the same as in the pre-task questionnaire with seven additional questions regarding the NPCs contribution. Moreover, the post-task questionnaire completed by the experimental group included, 74 additional items (Cronbach's $\alpha = .942$) developed based on features considered to be important for the agent supported game environment. These features concerned the agent supported serious game environment with respect to the agents' contribution, the overall usability and interface [52] of the game agent and the progress map. Briefly, the post-task questionnaire for control and experimental group included 86 and 160 items respectively. The measures used align to the research questions as follows: Sections (a) and (b) of the questionnaires are used to evaluate the students' attitudes, while sections (c), (d) and the additional post-questionnaire items evaluate the effect of the AI enhanced game on the class environment and its acceptance. Team performance was evaluated using the score value and the PGA's messages displayed during the games.

3.5 Procedure

The experiment was conducted based on the OSgame, which was planned to take place as a tournament with a duration of two and a half months. The tournament began with 15 teams, playing in five leagues. All teams were involved during the qualification phase, playing four OSgames each, approximately every 15 days. The eight teams with the higher ratings qualified to the semi-finals, while the two highest scoring teams from each semi-final game played at the final OSgame, from which the winning team emerged. The time period between qualification phase, semi-finals and final OSgames was seven days (Appendix, Fig. 1; presents graphically the structure of the OSgame Tournament, which can be found on the Computer Society Digital Library at http://doi.ieeecomputersociety.org/10.1109/TLT.2016.2521649). Concerning the team formation, students were organized into fifteen teams (Team 1 to Team 15) of two or three members each.

The teams were formed based on a "Team formation formula" (1), which was invented and applied to ensure heterogeneity within teams members and homogeneity between teams, providing a similar average level of technological experience, familiarity and preferences concerning virtual learning environments and 3D computer games. According to [53], heterogeneous teams seem to foster improved peer interactions and result in improved learning outcomes. Table 5 provides information about the parameters of the formula, their description and weight (columns 1 to 3). Weights were determined based on research team's considerations for the group formation criteria. Each parameter was weighted individually. A higher weight is given to the previous experience in the OSgame, which was considered of particular importance.

$$\begin{aligned} \textit{Team Formation Indicator}(\mathbf{TFI}) &= (\text{LikeGames} * 1.3) \\ &+ (\text{LikeVLEs} * 1.2) + (\text{SelfEfficacyGames} * 1.3) \\ &+ (\text{OSgameExp} * 5) + \text{VLEsExp}. \end{aligned} \quad (1)$$

TABLE 6
Descriptive Statistics for Control and Experimental Group on Each Pre-Post Dependent Variable

Variable	CONTROL Group				EXPERIMENTAL Group			
	PRE		POST		PRE		POST	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Attitude towards course	**3.90**	**.49**	**3.91**	**.39**	**3.83**	**.44**	**3.97**	**.41**
Course Value	3.99	.60	4.03	.38	3.89	.48	4.02	.46
Course Enjoyment	3.77	.53	3.79	.49	3.76	.46	3.91	.52
Course Motivation	4.00	.50	3.94	.42	3.87	.54	4.00	.53
Attitude towards games	**3.81**	**.63**	**3.94**	**.48**	**3.67**	**.48**	**3.84**	**.47**
Game Value	3.83	.60	3.86	.54	3.61	.66	3.69	.67
Game Enjoyment	3.84	.68	4.02	.48	3.70	.44	3.98	.40
Game Motivation	3.74	.74	3.96	.50	3.75	.50	3.89	.47
What is happening in this class	**3.03**	**.80**	**2.96**	**.69**	**3.06**	**.50**	**3.27**	**.43**
Cohesiveness	3.36	.82	3.29	.61	3.38	.54	3.63	.39
Collaboration	3.31	.81	3.20	.82	3.19	.71	3.43	.63
Involvement	2.42	.99	2.39	.99	2.61	.75	2.76	.68
Perceived usefulness of the hypothetical existence of agent	**4.21**	**.54**	**4.04**	**.55**	**3.85**	**.55**	**4.10**	**.36**

First, in order to form teams, the *"Team Formation Indicator"* for each student and the *"Team Formation Indicator"* mean for all students have to be calculated. The highest value that the formula results is 25 and identifies the most technologically appropriate subject for this particular study. The sample of this study resulted a *"Team Formation Indicator"* $\text{mean} = 12.0$, while each student's indicator ranged from 6.07 to 23.70. Subsequently students' teams were formed based on these values and by ensuring that the new team indicator average is close to the general average (+−0.5); all teams of the presented study have a *"Team Formation Indicator"* between 11.5 and 12.5.

The participating students were asked to complete two questionnaires: a) the pre-task questionnaire before the beginning of the OSgame tournament and b) the post-task questionnaire after finishing the OSgame tournament. For the control group the post-task questionnaire was the same as the pre-task one. The students who belonged to the experimental group were called to answer additional questions at the post-task questionnaire, concerning the intelligent features of the game environment.

4 Results

First, an initial analysis of variance (ANOVA) was conducted on pre-test variables to ensure that there were no existing differences among the control and the experimental group. A 0.05 level of significance was used for the statistical test.

TABLE 7
NCOVAs Summary Table on Dependent Variables for Control and Experimental Group

Dependent Variable	F	P-values
Attitude towards course	1.51	.228
Attitude towards games	.03	.863
What is happening in this class	4.23	.048*
Perceived usefulness of the hypothetical existence of agent	1.46	.236

*$p < 0.05$

Results indicated that the two groups were not systematically different with respect to students' attitudes, students' perception of their learning environment and the perceived usefulness of the hypothetical existence (p values for all pre-test depended variables were greater than 0.05). In detail, the results indicated no significant main effects of students' attitudes towards course ($F_{1,32} = .183, p = .671$), attitudes towards games ($F_{1,32} = .561, p = .459$), what is happening in this class ($F_{1,32} = .014, p = .906$), or perceived usefulness of the hypothetical existence of agent ($F_{1,32} = 3.663, p = .065$) on participating groups. Then, to test the first and second research questions, subsequent statistical tests were applied: a) an Analysis of Covariance (ANCOVA) in order to explore possible statistical differences between the control and experimental groups; the ANCOVA used the pre-test scores of the dependent variables as covariates (alpha level of 0.05), b) discriminant analysis to determine which variables best discriminate between the control and experimental groups, and c) a paired t-test to explore possible statistical differences between the pre and post variables' means for the experimental group. For the evaluation of the game agent on teams' performance (third research question), a log file analysis of all the messages sent by the agent was conducted. Finally, descriptive statistics of additional intelligent features and semi-structured interviews were utilized to shape some insight on the students' experience during the game and identify issues needed to be improved in future work.

4.1 Control versus Experimental Group

Table 6 presents the mean scores and standard deviations for the control and the experimental group on each pre and post dependent variable and their factors.

Four ANCOVAs were conducted to determine statistically significant differences between the control and experimental groups on each dependent variable as shown in Table 7. The covariates for each ANCOVA consisted of the pre-test scores of the corresponding dependent variable. An alpha level of 0.05 was used for all statistical tests. Results indicated that there was a significant effect of group type on the *'What is happening in this class'* variable controlling

TABLE 8
Paired Samples t-Test and Cohen's d Effect Size for Experimental Group

Variable	*t*-test	P-values	Cohen's *d*
Attitude towards course	−2.372	**.028***	.53
Course Value	−1.524	.144	–
Course Enjoyment	−2.073	.052	–
Course Motivation	−1.412	.174	–
Attitude towards games	−2.930	**.009***	.66
Game Value	−1.304	.208	–
Game Enjoyment	−3.156	.005*	.71
Game Motivation	−1.629	.120	–
What is happening in this class	−2.023	**.057**	–
Cohesiveness	−2.364	.029*	.53
Collaboration	−1.340	.196	–
Involvement	−1.902	.072	–
Perceived usefulness of the hypothetical existence of agent	−1.952	.066	–

*$p < 0.05$

for the pre-test score of the same variable ($F_{1,32} = 4.227, p = 0.048$). No significant effect of group type was found on the rest of the dependent variables ($p > 0.05$). The ANCOVA analysis was also applied to further investigate the three factors of the '*What is happening in this class*' variable that might have had a significant effect of group type. The pre-test scores of the corresponding factor were used as covariates for each ANCOVA (alpha level of 0.05). Results demonstrated a significant effect on the *Cohesiveness* factor, $F_{1,32} = 5.216, p = 0.029$. No significant effect of group type was found on *Collaboration* and *Involvement* factors of the variable ($p > 0.05$).

Follow-up discriminant analysis was performed to determine which variables best discriminate between the control and experimental groups and to uncover the dimensions of values that differentiate them. The values included the differences in pre and post test means scores for the students' '*attitude towards course*', '*attitude towards games*', '*What is happening in this class*' and '*Perceived usefulness of the hypothetical existence of agent*'. An alpha level of 0.05 was used for the statistical test. Results indicated that the way students perceive the hypothetical existence of an agent ('*Perceived usefulness of the hypothetical existence of agent*') significantly differentiated the two groups, Wilks Lambda = 0.865, Chi square(18) = 4.583, $p = 0.032$. The rest variables did not reach significance. Finally, two paired t-tests were conducted to explore possible significant differences between the pre and post mean variables for both the control and the experimental group. The paired t-test applied on the control group did not show any statistical differences between any of the pre and post variables' means. In contrast, pairwise comparisons between the pre and post evaluation for the experimental group (Table 8) indicated the following statistically significant differences between the groups of 0.05 level:

a) between the *pre-'attitude towards course'* ($M = 3.83, SD = .44$) and *post 'attitude towards course'* ($M = 3.97, SD = .41$), $t(19) = -2.37, p = 0.028, d = 0.53$, b) between the *pre-'attitude towards games'* ($M = 3.67, SD = .48$) and *post 'attitude towards games'* ($M = 3.84, SD = .47$), $t(19) = -2.93$, $p = 0.009, d = 0.66$. More specifically, statistically significant differences found between the *pre-'game enjoyment'* ($M = 3.70, SD = .44$) and *post-'game enjoyment'* ($M = 3.98$, $SD = .40$), $t(19) = -3.16$, $p = 0.005, d = 0.71$, and c) between the *pre-'cohesiveness'* ($M = 3.38, SD = .54$) and *post-'cohesiveness'* ($M = 3.63, SD = .39$), $t(19) = -2.36, p = 0.029$, $d = 0.53$, which is one of the three factors of *'what is happening in this class'* variable. Considering the small number of participants give evidence to further investigate the outcomes. Thus, the Cohen's d index was extracted for all variables that indicated statistically significant differences in order to establish each variable's effect size and explore their practical significance (Table 8, column four). The Cohen's d values for *'attitude towards course'* ($d = 0.53$), *'attitude towards games'* ($d = 0.66$), *'game enjoyment'* ($d = 0.71$) and *'cohesiveness'* ($d = 0.53$), suggest a medium effect.

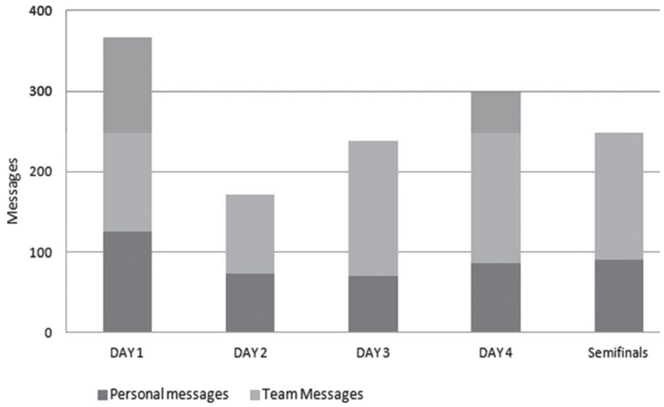

Fig. 6. Team versus Personal messages during the Tournament.

4.2 Log Files Analysis

All messages sent by the agent during the OSgame were saved in a database, in order to keep track of its activity. The data concerning the game agent was collected only for the experimental group. The game agent sent in total 1,321 messages of which 446 (34 percent) were team messages and 875 (66 percent) personal messages (Fig. 6). Moreover, Fig. 6 suggests evidence of the need to enhance collaboration through personal messages.

The information gathered from the agent's database is visualized below with a scatter diagram (Fig. 7). In detail, Fig. 7 presents graphically the mean scores for each day of the OSgame tournament for the control and experimental group, showing that mean scores for the experiment group were higher than the control group almost for all days of the tournament. Observations of teams' scatter diagrams, showing the progress of agent's messages and team's score during the OSgames, revealed a potential positive effect of agent's activity on the teams' performance. Indicatively, there was a strong linear relationship ($R^2 = .93$) between the number of messages delivered by the agent and the teams' score, during the semifinal day for team number 10. Similarly, relationships were also found for the other participating teams (ranged from 0.86 to 0.93).

4.3 Students' Experience on Intelligent Game

In order to obtain additional information on impressions, problems and suggestions and gain some insight on the students' experience of the AI enhanced educational game

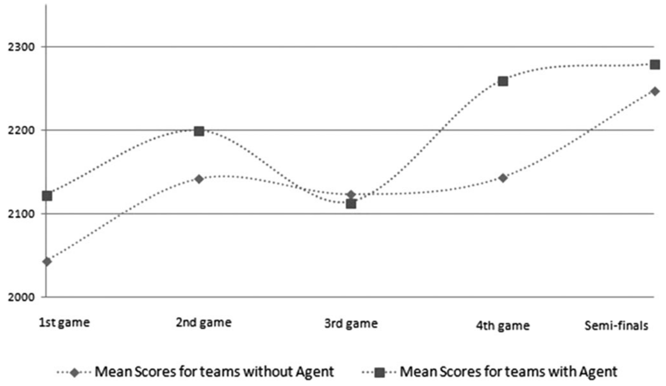

Fig. 7. Mean scores for teams with (experimental group) and without agent (control group).

activity, semi-structured interviews and additional evaluations were carried out.

4.3.1 Users' Evaluation of the Intelligent Game Features

After the OSgame Tournament, students belonging to the experimental group evaluated the AI enhanced game environment. In detail, the descriptive statistics of the experimental group's answers concerning the technical attributes of the pedagogical game agent and the user interface satisfaction [52] of both the pedagogical game agent and the progress map interface are presented in detail in Table 9. Students expressed their satisfaction regarding the intelligent with average scores higher than 3.0 in a five-point Likert scale.

During the optional familiarization phase students had the opportunity to visit the virtual space of the game and use the NPCs for virtual tour guides. Seventeen out of 34 students (50 percent) chose to participate in the optional familiarization phase, while the rest of the students, who did not participate, were apparently already familiar with the offered technology. Fifteen out of the 17 students participating in that phase chose to utilize the NPC, while 82.4 percent $(N = 14)$ out of them stated that they became aware of NPC's presence in the virtual game environment. Moreover, the students evaluated the NPC's existence with an average score of 3.21 $(M = 3.21, SD = .49)$, which was perceived from the students helpful with an average score of 3.21 $(M = 3.21, SD = .89)$, useful with an average score of 3.43 $(M = 3.43, SD = .76)$ and enjoyable with an average score of 3.36 $(M = 3.36, SD = .50)$. The majority of the students strongly agreed or agreed $(cumulative\ percentage = 64.3\%)$ that it was easy to recognize the NPC's avatar. Concerning the chat bot evaluation $(M = 3.54, SD = 0.46)$, results cannot be used to draw conclusions because of the very small sample; only four students did recognize and did interact with the bots. Thus, the results indicated that the chat bots have not been noticed by the majority of the students (80 percent).

4.3.2 Interview Analysis

After the OSgame Tournament, semi-structured interviews were carried out face to face with the student experimental group $(N = 20)$. Since the aim of the interviews was to gain a further understanding of students' opinions and some insight on the their experience and preferences regarding the AI supported game activity, the samples selected was

TABLE 9
Escriptive Statistics for PGA and Progress Map

Variables	Mean	Std. Dev
User Interface Satisfaction from PGA	3.01	.50
Screens of PGA	3.69	.79
Terminology of PGA	3.38	.52
Learning PGA	3.12	.81
Capabilities of PGA	3.02	.77
User Interface Satisfaction from Progress Map	3.39	.56
Screens of Progress Map	3.70	.76

the students in the experimental group who played the OSgame with the additional AI features. The conducted interview was based upon a designed questionnaire of 15 open-ended and one closed-ended questions. The twenty students were independently interviewed by a two-person interview team within one day, in a university classroom. The interview questions were transcribed and classified into three categories corresponding to the agent's types. The following contain the analysis of the interviews:

Pedagogical Game Agent. Out of the 20 interviewed students: a) 16 responded that the messages relating to the promotion or demotion of their team and its ranking update made them to try harder to win, b) 15 responded that the messages helped them to better understand the progress of their team throughout the game, and c) 15 declared that the reward messages encouraged them to believe that they can help their team and contribute in winning the game. Students expressed their preference of the agent's participation in the team chat rather than the personal chat. The majority of the students (15 out of 20) faced no difficulty and they were not bothered by the frequency of the displayed messages. However, students mentioned some negative aspects of the pedagogical game agent. In specific, there were cases, even though few, in which they felt disturbed by the rate the messages were send; this is in conjunction with previous research findings [34]. Furthermore, there were also few students that felt disappointed due to the fact that chatting with the pedagogical game agent was not provided. Finally, students mentioned that the pedagogical game agent failed to help their teams to develop a strategy during the game.

Chat bots. Students declared that they have avoided posing questions to the bots. They argued about their choice quoting the following reasons: a) the competitive nature of the game imposed a particular demand for speed and time was so valuable that they did not want to waste it trying to talk with the bots and b) they implied that the bots' role within the game was not clear. Interviewers indicated that they did not know what to ask or did not ask in order to avoid losing points. Many of the students thought that the chat bots provided assistance, for example, on the location of the questions their team had not found yet, or even hints for correct answer to some questions. Regarding the bots' presence and appearance, students declared that these were interesting and attractive. Nevertheless, students also hoped that they could change the appearance of the agent and suggested this feature for future implementation.

Non-Playing Characters. Students who used the NPC guide at the familiarization phase said they were satisfied with the presence of NPCs in the OSgame. Students that had previous experience with NPCs understood their role without any difficulty. Interviewees thought that the tour provided by the NPCs was brief and practical. Moreover, they suggested that the NPCs should not only offer tour guide to the game space but should also have the ability to provide additional information about the game. Finally, students suggested using similar agents also in other educational online activities.

5 Discussion

This study proposed and evaluated the efficacy of an AI supported serious game environment by providing different kinds of agents and intelligent interfaces aiming to augment collaborative educational games and facilitate the educational procedures in a 3D learning environment. The pedagogical design of the intelligent environment employed motivational strategies based on an extended proposed ARCS model. The extended model appends collaboration to the already existing factors of the ARCS model, namely attention, relevance, confidence and satisfaction, in order to meet the requirements of an AI enhanced collaborative educational game environment, provide strategies on motivating students' collaborative interactions and offer an appealing learning setting that might positively affect students' attitudes.

The university students who comprised the sample were quite familiarized with technology, the majority of them were self confident in using 3D games and positively inclined towards computer games, facts which specified ideal ambience for impending research. The design of the intelligent features also focused to support the collaboration among students during the OSgame. It is worth mentioning that all teams qualified for the OSgame Tournament final belonged to the experimental group, which had all the intelligent game features at their disposal. Regarding the pedagogical game agent, students recognized its usefulness in providing help on the game process that offered a better overview of the game in a collaborative manner. Pedagogical game agent's team messages seem to have initially created the sense of being a team and then to have boosted it. In addition, the examination of the variables that best discriminate between the control and experimental groups revealed that the way students perceive the hypothetical existence of an agent, significantly differentiated the two groups. The experimental group's acknowledgment for the provided agent supported environment is substantiated by the way students perceived the hypothetical existence of an agent after the educational activity, which significantly differentiate them from the students belonging to the control group. This finding indicates the acknowledgement of the additional support for the experimental group and the need for more assistance for the control group. More particularly, the features that have to be reconsidered relate to the agent's user interface, the enrichment of the offered AI capabilities and the simplification of the overall AI functionality in order to be more understandable and easy to be learned by students.

Albeit these outcomes, there were also students, though only a few, who expressed negative views about the agent during the interview. This is not surprising if we look at similar researches in [34] literature review, from which it emerges that agents can also evoke strong negative reactions [34]. One of the challenges for this study was to provide all students with an environment, in which they could feel "cozy" by eliminating the anxiety of guidance in an unknown three dimensional large virtual space. Regarding the chat bots, although students had been accurately informed about the bots' role and how to interact with them, they preferred not to talk to them for fear of losing critical game points and also due to lack of time. As such, it is suggested that these bots should be used only in educational settings in which time is not critical for the educational process. The research questions are discussed in the following paragraphs.

RQ 1: "In what terms does an agent supported serious game environment affect student attitudes towards the course and games?" Student attitudes towards the course and the game were evaluated [50], based on value, enjoyment and motivation factors. The findings of this research study did not reveal significant main effects of the agent supported game environment in any of the dependent variables. The agent supported serious game environment did not positively or negatively impact students' attitudes towards the course or the game. While the improvements on students' attitudes between control and experimental were not statistically significant, when compared using the ANCOVA analysis, it is worth mentioning that there was an interesting auxesis on their pre- and post-evaluation scores for the experimental group. In specific, results derived from the paired t-test indicated statistically significant differences between the 'attitude towards course' and the 'attitude towards games' between the pre- and post-evaluation means scores for the experimental group. Moreover, the analysis of students' attitudes towards games identified statistically significant difference in terms of 'enjoyment'. Complementarily, Cohen's d effect size values for the above variables suggest a moderate practical significance, indicating that attitudes towards course and games have a medium effect when using a game agent.

RQ 2: "In what terms does an agent supported game environment affect the classroom environment?". Regarding the effectiveness of the agent supported game environment in the "face-to-face" classroom environment, results provide evidence that the intelligent game environment improved cohesiveness for students in terms of helping, supporting and becoming connected to each-other as opposed to the rest that lacked in agent support. Students who played the game with the agents' support appear to have benefited in terms of cohesiveness. While the improvements on students' collaboration and involvement were not statistically significant, it is worth mentioning that there was an interesting auxesis on their scores for the experimental group. On the other hand, regarding the control group, all factors which determine the situation in class (cohesiveness, collaboration and involvement) showed a decrease at the post evaluation. Finally, the NPC tour guide, which was also provided by the agent supported game environment, appears to have gained the attention of the students; it was perceived by the students as enjoyable, helpful and useful. Even though most of the students were satisfactorily confident in using 3D games, only a small percentage did have previous experience in virtual environments and even less in the OpenSim environment, while there were also students who expressed their need for additional assistance in order to act in such a 3D game environment; this fact made the use of the NPC guide useful for students who had small or even not experience at all.

RQ 3: "*What is the impact of the support provided by a pedagogical game agent on the performance of a team?*" The findings of this research study confirmed the pilot study's results, which stated the capability of a pedagogical game agent to have a positive impact on the performance of a team. Real time data, collected from the agent database, revealed a strong linear relationship between the number of the messages sent by the agent to a team and the teams' performance in terms of score and ranking. Thus, when a team presents an inertial performance the agent increases his messages. Additionally, the linear relationships between agent's messages and teams' scores showed a symmetry, which furnishes evidence for the agent's feature to motivate students and support a collaborative game. Finally, results revealed that collaboration and teams' performance through AI enhanced collaborative game environments might benefit by giving more attention to each student individually and by supporting them through personal messages.

6 Limitations

The following limitations must be considered when examining the results of this study for an agent supported serious game environment used in 3D collaborative games: (a) Game characteristics, such as a limited time duration or an immersive 3D environment, are major factors that could create anxiety and affect students' attention leading them to ignore or even be annoyed by the presence of an agent. Thus, an agent supported serious game environment should be very carefully and meticulously designed in conjunction with game features where appropriate. (b) Participants in this study were informatics department students and had a satisfactory feeling of confidence in using 3D games, a fact that may have affected the results. (c) Agent's representation: the pedagogical game agent was chosen to interact with the students in a conversational mode, without any embodied representation in order to reduce the cognitive overload and to operate in a discreet manner.

7 Conclusions and Future Work

This research study proposed and evaluated an agent supported serious game environment for a 3D collaborative game in the OpenSim platform involving university students. With regards to students' attitudes, results revealed that students provided with the agent supported game environment did not change their attitude towards the course and games. With regards to "*what is happening in this class*", results revealed that students who played the game with the agents (experimental group) improved their cohesiveness in contrast to a control group that lacked in agent support. Based on the presented results, it can be surmised that there is a beneficial impact to the team cohesiveness of the participated students which was also depicted at teams' performance during the game educational activity. This provides evidence of the PAs' usefulness in collaborative immersive games and their ability to support game based collaborative learning. Concerning the utilization of NPCs as tour guides, they are suggested when a learning procedure takes place in a three dimensional space. On the other hand, it is recommended that bots are used very carefully if the users operate in intense time pressure; the time limit seems to negate the usefulness of the bots. Concluding, the utilization of a whole intelligent environment, in a 3D educational game, seems to facilitate game based learning. Future research work includes the design of a research study, which will evaluate the impact of agents on cognitive outcomes using a less stressful educational setting, where 3D human like PAs will be able to deliver messages also in a discreet manner through non-verbal communication [55].

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