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The Effectiveness of Embodied Pedagogical Agents and Their Impact on Students Learning in Virtual Worlds

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Abstract: Over the last years, the successful integration of virtual reality in distance education contexts has led to the development of various frameworks related to the virtual learning approaches. 3D virtual worlds are an integral part of the landscape of education and demonstrate novel learning possibilities that can open new directions in education. An important aspect of virtual worlds relates to the intelligent, embodied pedagogical agents that are employed to enhance the interaction with students and improve their overall learning experience. The proper design and integration of embodied pedagogical agents in virtual learning environments are highly desirable. Although virtual agents constitute a vital part of virtual environments, their exact impact needs are yet to be addressed and assessed. The aim of the present study is to thoroughly examine and deeply understand the effect that embodied pedagogical agents have on the learning experience of students as well as on their performance. We examine how students perceive the role of pedagogical agents as learning companions during specific game-based activities and the effect that their assistance has on students' learning. A concrete experimental study was conducted in AVARES, a 3D virtual world educational environment that teaches the domain of environmental engineering and energy generation. The results of the study point out that embodied pedagogical agents can improve students' learning experience, enhance their engagement with learning activities and, most of all, improve their knowledge construction and performance.

Keywords: embodied pedagogical agents; 3D virtual worlds; students' learning experience; learning effectiveness; engagement; gamification

1. Introduction

During the last decade, technological advances greatly affected educational systems and have revealed novel tools and methods that are more attractive to students and have the potential to provide more efficient educational processes. Virtual reality constitutes an innovative learning technology that possesses great educational potential and is becoming an emerging technology in the educational landscape. Educational platforms that are based on virtual reality have the possibility to provide students and teachers with a wide spectrum of training procedures and have been used in many challenging fields and domains [1–3]. Virtual reality educational systems can be very assistive to both teachers in their teaching processes, and most of all, to students in their study, knowledge acquisition and understanding [4]. What is more, virtual reality has the potential to enhance the learning experience of the students and also improve the effectiveness, the attractiveness and the learning impact of the learning procedures [5,6].

A crucial characteristic of 3D virtual reality platforms relates to the personal and social affordances that users experience. It is pointed out in many studies that an important issue of distant educational platforms concerns the lack of personal and social presence [7,8]. In order to face this issue in virtual world educational platforms, embodied pedagogical agents can be utilized with the aim to enhance the social interaction with the learners. In educational environments that are based on 3D virtual worlds, pedagogical agents are mainly embodied avatars, which are employed to support students and scaffold the instructional aims [9]. The integration of embodied pedagogical agents in 3D virtual world educational systems can enhance their intelligence and believability, and most of all, improve the interaction with the students [10,11]. The main impact of embodied pedagogical agents refers to the enrichment of the virtual learning environments with social aspects, better interaction with the users so as to support more adaptively the learning processes and enhance students learning experience [12]. In this spirit, pedagogical agents can have a central role in 3D virtual learning environments as they can serve diverse instructional goals and have a wide range of tasks and functionalities [13]. Embodied pedagogical agents are also utilized to scaffold self-learning by mimicking, to some degree, the role of the tutor. Such entities have also the ability to become learning companions as they can provide guidance and assistance to students during the learning process, [9]. Embodied pedagogical agents have also great promises for sophisticated, problem-solving assistance through the use of visualization techniques. Moreover, they can enhance students' learning with the delivery of individualized feedback, and in addition, can engage students in learning scenarios [14]. An area where the added-value of pedagogical agents is also identified concerns the development of the social and sensual presence (immersion), which leads students to feel and behave similarly to the way that the human-to-human interaction and communication occurs [15–17].

The proper design and integration of embodied pedagogical agents in virtual reality environments are necessary and highly desirable. The purpose of this article is to examine the learning effectiveness that agents have on students' learning experience, knowledge construction, and performance in 3D virtual world educational environments. In addition, we examine their role as learning companions and investigate the effect that they have on students' engagement as well as on their cooperation and communication. Furthermore, we examine how students perceive the role of pedagogical agents as learning companions during specific game-based activities and the effect that their guidance has on students' learning. A concrete evaluation was performed in AVARES 3D virtual world that teaches topics of the course of environmental engineering and the generation of energy from renewable sources. Students from our university studied in the 3D virtual world and participated in a wide spectrum of gamified learning procedures under different conditions and situations in terms of feedback, guidance, and presence of embodied pedagogical agents. The results point out that the presence and the behavior of the embodied pedagogical agents can have a substantial impact on students' learning experience, improve their knowledge construction and their performance.

The remainder of the article is structured as follows: Section 2 presents background topics on virtual pedagogical agents and related work on their use in virtual learning environments. Section 3 presents the AVARES 3D virtual world, analyzes its functionality and infrastructure, the learning activities designed and the functionality of the pedagogical agents integrated into the environment. Section 4 presents the design elements of the experimental study and illustrates the results that were collected. Section 5 discusses the results and the main findings, and finally, Section 6 concludes the article and draws the main directions for future work.

2. Related Work

Embodied pedagogical agents are virtual characters that have a body and can interact and communicate using voice, gestures, and facial expressions for instructional purposes [18]. In general, the embodied pedagogical agents are distinguished from simple software agents that have autonomy but do not possess a virtual body and lack in communication means and mediums. Embodied agents may be particularly suitable for virtual environments. The main type of virtual agent concerns the virtual embodied pedagogical agents, which constitute a predominant type utilized in virtual reality educational environments. Embodied pedagogical agents have been used in various ways to deliver educational content as part of a vision that a virtual agent can advantageously influence learning [19,20].

In recent years, the examination of the effectiveness of embodied pedagogical agents has attracted the increasing attention of researchers. In the literature, there is significant research interest and many works study the effectiveness of virtual agents. In most cases, research works point out that virtual characters, even in cases when they possess minimal expressiveness, can have a positive influence on the learning experience of students, a phenomenon that is often called persona effect [14].

The integration of virtual characters in various pedagogical settings in virtual reality environments can enhance the learning experience [13] by providing additional incentives for interaction and thus, engagement [21]. However, studies have pointed out that the interaction necessitates the active coordination and cooperation of at least two intelligent parties, which can be limited due to the absence of social intelligence [13]. Other works point out that learners experience more positive situations and emotions during interaction with a virtual agent that provides positive instead of negative feedback [22], and also that they can perform better in problem-solving procedures after having participated in educational games with polite instead of impolite agents [23,24].

The exact impact of the embodied pedagogical agents on learning outcomes is, however, inconclusive in the literature [18]. Reports also show that students who participated in educational games about plants did not perform better on attitudinal measures and knowledge recall when they were engaged with agents compared to situations that did not include additional support from agents [25]. Past empirical work has indicated that the way a virtual agent is introduced to the virtual world and the students may affect the learning outcomes [18].

The aim of the present study is to thoroughly examine and deeply understand the effect that embodied agents have on the learning outcomes of students as well as on their learning experience, engagement, and performance. Although the virtual agents constitute a vital part of virtual environments their exact impact is yet to be addressed and examined [18]. Therefore, the main contribution of the present study concerns the examination of the following three hypotheses:

H1: Embodied pedagogical agents improve students' learning experience in virtual world educational environments.

H2: Embodied pedagogical agents improve students' performance and comprehension in virtual world educational environments.

H3: Embodied pedagogical agents enhance students' engagement and their cooperation and communication with peers.

The study aims to shed light on these hypotheses and examine the functionality of the embodied pedagogical agents in the AVARES virtual reality educational environment that was used. In the next sections, we present the environment, analyze the learning activities it offers to students, and examine the impact that pedagogical agents have on students' learning.

3. The AVARES Virtual Reality Educational Environment

AVARES is a 3D virtual world educational environment that teaches aspects of environmental engineering and energy generation from renewable sources. Its purpose is to help both students to learn more efficiently and teachers to better teach courses in the fields of environmental engineering and energy generation. It was developed in the context of a transnational European funded project in 2014, and it is used in our university since then. The 3D world aims to replicate and simulate the real world in order to offer students the possibility to study and learn in a learning environment that is very close to reality.

3.1. Educational Infrastructure

The AVARES 3D virtual world has various virtual constructions, power plants, buildings, and educational infrastructure that resembles the real world and visualizes the way that various procedures are performed. Students have the opportunity to visit virtual constructions and plants in order to examine the exact way they operate and the procedures they perform. In addition, an important aspect of the 3D virtual world is that it offers training activities that rely on the principles of constructionism [26,27]. In greater detail, parts and modules of various constructions and machines can be combined together and interlinked so as to create complex and sophisticated constructions. Students can examine the parts of constructions and can inspect the way they operate. Figure 1 illustrates a virtual construction that visualizes and simulates a wind turbine.

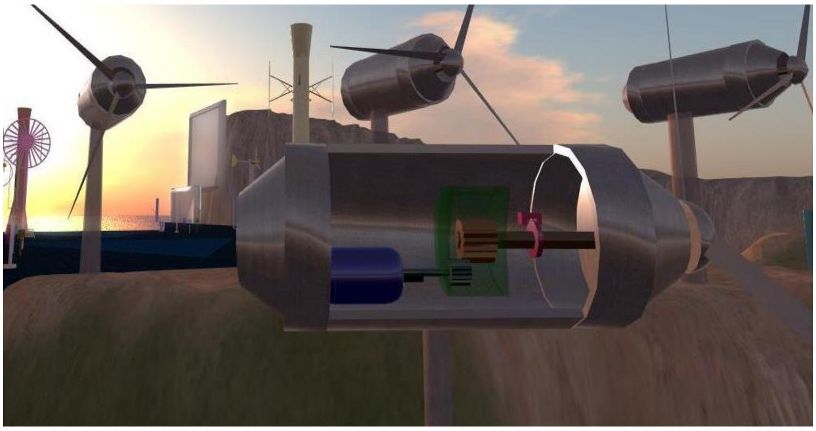

Figure 1. Constructions in the 3D virtual world representing wind turbines.

In the 3D virtual world environment, students can interact with the 3D constructions so as to inspect them and examine their operations and functions. Individual basic virtual objects can be combined together in order to create complex machines that perform specific procedures. For example, basic transmission gears, rotors, and cables can be combined and interlinked to visualize the functionality of a real wind turbine that converts wind kinetic energy to electrical energy. The design of the 3D constructions and the machines aims to assist learners in developing proper mental models of the procedures by visualizing and simulating their exact functionality.

The 3D virtual world environment, offers learners various courses on the fields of environmental engineering and energy generation from renewable sources. Each course consists of various learning topics and has a wide range of complementary multimedia learning material in various formats. Learners can study the theory of each course that comes mainly in the form of text-based presentations. Therein, students have the opportunity to study in the virtual world the theoretical parts via presentations and examine the operation of corresponding 3D virtual constructions that simulate and visualize theoretical concepts and procedures. Figure 2 depicts an example of a virtual 3D construction that illustrates the main layers of photovoltaic cells and visualizes the functionality and the operations that take place at each layer.

Learners have the opportunity to interact with the virtual constructions by clicking on the different parts. Accordingly, the animation process of specific simulations is initiated, and explanation messages appear, so as to describe the characteristics of the specific part, its functionality, and the specific processes that the part performs. In this line, abstract and theoretical concepts are visualized and associated with concrete functionalities and virtual animations in order to assist students to better understand and form proper mental models.

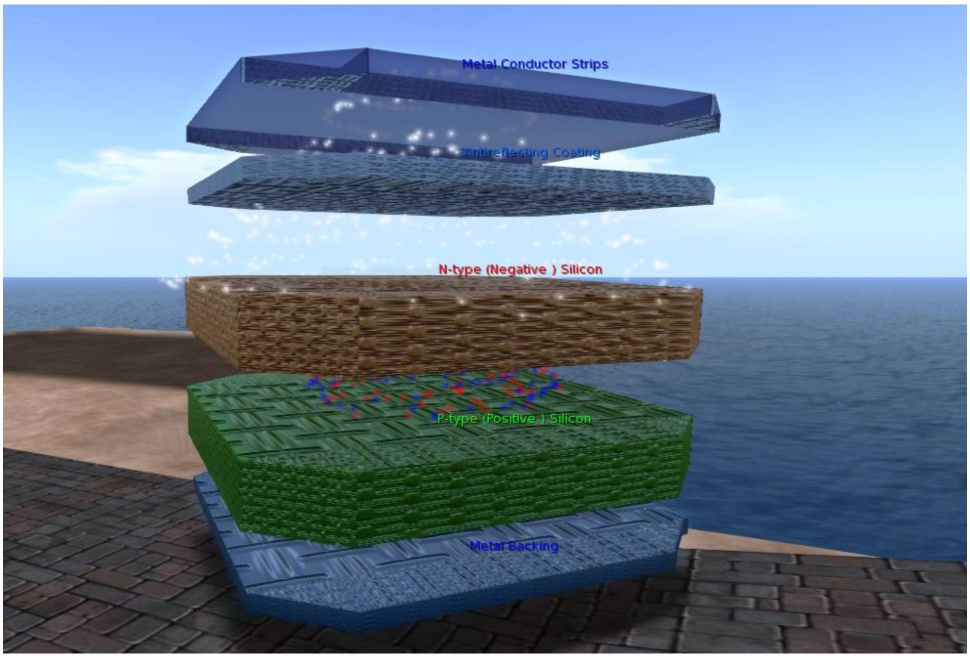

Figure 2. Layers of photovoltaic panels in the environment.

3.2. Learning Approaches and Training Activities

In the AVARES virtual world environment, a wide spectrum of learning scenarios and approaches has been formulated and are available to learners. In general, the environment offers educational procedures and training activities that rely on the principles of constructionism and gamification [28]. Learners can participate in activities that require them to manipulate and interact with constructions in the context of gamification scenarios. In this context, parts and modules of various constructions and machines can be combined together and interlinked so as to create complex and sophisticated constructions, fix malfunctioning devices, etc. For example, learners can participate in learning scenarios where electrical failures have occurred and have blacked out energy production in a factory. Students can work as individuals or as small teams to diagnose the failure and make proper actions to fix it. Therefore, in order to fix the problem and accomplish a learning activity (e.g., a blackout, a malfunctioning wind turbine, etc.), learners have to investigate the corresponding power plants and machines, diagnose the origin of the issue and the malfunction and after that specify the appropriate actions that have to be made in order to fix it. The solution can require specifying first the faulty parts of a malfunctioning machine and then replacing them by determining the appropriate items that are suitable and have the proper requirements. Then, after students have successfully repaired the malfunctioning machine and have resolved the problematic situation, proper rewards can be given to them. What is more, in many training activities, students can be given practice exercises, consisting of sets of questions to answer, that require that they visit factories and examine special procedures or devices and interact with them. The purpose can be to investigate these processes and interact with the machines and the corresponding devices in order to comprehend the way that they function and, after doing so, determine the proper answers to the questions. In the context of the training activities, students can participate as individuals or even as small teams that have two or three students and so the training activities can cultivate and improve their collaboration and communication skills. What is more, the training activities can offer conditions that stimulate active cooperation among the students and the embodied pedagogical agents in the educational environment [29].

The 3D environment provides a wide spectrum of assessment opportunities. In addition to the hands-on experience and training activities that learners can have in the environment, various exercises and tests are also available for each course and can help students to assess their knowledge and their comprehension in various topics and procedures (see, for instance, Figure 3).

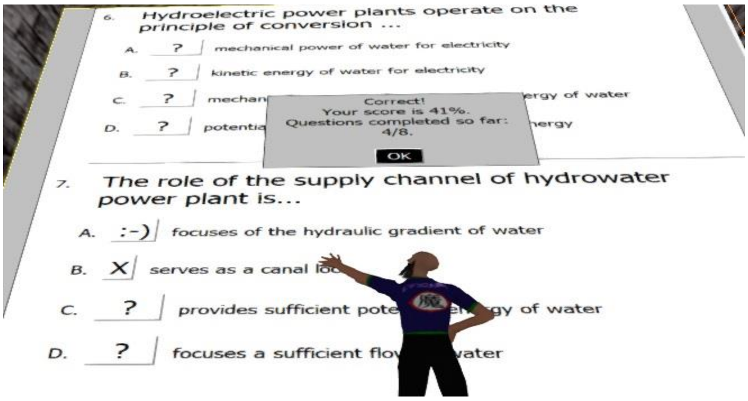

Figure 3. Example of multiple-choice exercises in the environment.

All the actions of the students in the environment are recorded and automatically analyzed. Therefore, the system is able to determine the knowledge level of the student in each concept of the course based on the performance in the exercise and the training activities.

3.3. Embodied Pedagogical Agents

In the AVARES environment embodied pedagogical agents are formulated and integrated into the 3D world to accompany students during the training activities and support them (see, for instance, Figure 4). The pedagogical agents are virtual avatars that are programmed to have specific behavior and functionality and are controlled by scripts. The agents can support students' learning, guide them during the learning activities and the training scenarios. Their aim is to resemble, to some degree, the role of a real tutor who supports students, stands by them, monitors, and supervises their actions in the environment and most of all helps them in the context of the training scenarios and exercises [30].

Figure 4. An example agent in the virtual world.

Learners in the environment, after having studied the theoretical parts of the course, have the opportunity to participate in the training scenarios and take exercises. The main aim of the training scenarios is to engage students and help them to put abstract theoretical knowledge into practice. Learners can communicate with the virtual pedagogical agents in the world and get learning activities and exercises, as discussed above. When a student or a group of students interact with an agent and get an activity to accomplish, the learning activity starts, and the virtual agent accompanies them during the activity. Moreover, students can ask for help, and the agent provides proper feedback and hints. The hints come mainly as confirmations whether a student's answer is correct or not, the delivery of bottom-up hints that provide students with the correct answer, and the related theoretical topics involved. Moreover, the agent can address a particular error or number of errors that the student made and provide guidance to learners as far as the next steps are concerned [31]. The agent's assistance mainly relates to the delivery of hint messages of what to do first/next and also hints to the theoretical concepts that are involved in the training scenario. The students, when they have completed a training activity, can get additional exercises and proceed to the following activities and scenarios. The training scenarios are provided to learners in an incremental difficulty level starting from easy ones and, as learners progress, more complex and difficult ones are becoming available.

4. Experimental Evaluations

An evaluation study was formulated in order to assess the learning effectiveness of the embodied pedagogical agents and specify their impact on students' learning. Specifically, the experimental studies aim to evaluate the way that students perceived the virtual pedagogical agents in the 3D virtual world educational environment and assess their assistance and guidance. For the purposes of the evaluation, a set of concrete experiments was carried out in our university, in the context of an energy course.

4.1. Participants

In the context of the study, one hundred forty-four (144) students enrolled in an undergraduate course at our university and participated in the experimental study as part of the course. The students were almost at the same age 20 and 22 (M = 20.68, SD = 1.33) and at the same year of study. Each condition was gender-balanced, with five females and five males in each group. The participants had prior experience of using 3D virtual world educational environments, and none of them had taken the course before. All the students were requested to participate in the study during the course, and they were informed that their data and personal information would be anonymous and only utilized in the context of the research study.

4.2. Methods and Results

The experimental studies consisted of two different scenarios and examined students learning experience and comprehension.

The first scenario involved an instance of the virtual world where students could study along with the pedagogical agents who provided them with different learning activities. After the start of a learning activity, the students were on their own to accomplish each activity. The students could ask for help and assistance, and hint messages were provided via the instant messaging chat area of the interface. The second scenario involved an instance of the virtual world where students could study and complete the learning activities with the full functionality of the embodied pedagogical agents. Specifically, at the start of the learning activities, the embodied pedagogical agent described the context of the activity and accompanied the student. The agent was all the time near the student walking side by side and provided students with the opportunity to interact, so as to get guidance on how to proceed with the activity and assistance related to possible errors made. The content of the system's guidance and assistance was exactly the same in the two scenarios. However, the agent was absent in the first scenario and all the help messages were provided as messages in the chat area of the environment.

An experimental/control, pretest/posttest approach was followed in the study. Its phases are illustrated in Figure 5. Initially, the participating students in the study were asked to create their accounts in the AVARES environment. During the registration, personal information such as gender, years of study, and contact information were requested. After that, the students were randomly divided into two size groups that had the same size of 72 students each, and were named GroupA and GroupB respectively. The rates of girls and boys in GroupA were almost the same as GroupB.

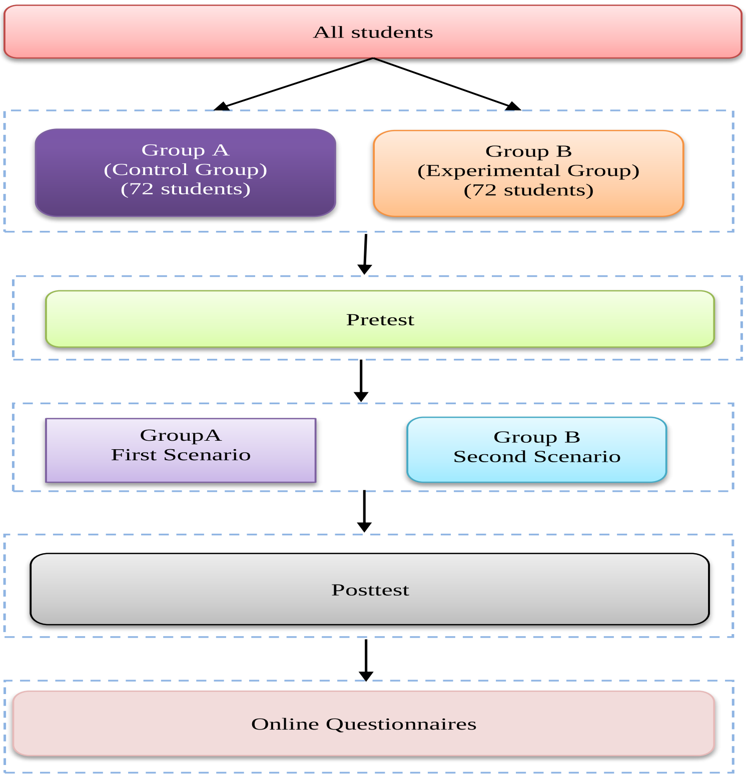

Figure 5. The main parts of the study.

All the students from both groups participated in and took a pre-test that aimed to assess their prior knowledge before the start of the learning phase in the AVARES environment. The pre-test consisted of multiple-choice questions, and its duration was 25 min. The experiment was conducted in the computer laboratory at the university. After the pre-test, the learning phase took place. The students from GroupA studied in an instance of the AVARES under the first scenario whilst, the students from GroupB in an instance under the second scenario.

In order to analyze students' performance, the mean value and the standard deviation were calculated for the pre-test. As shown in Table 1, the mean value and standard deviation were 4.201 and 0.540 for the experimental group (GroupA), and 4.368 and 0.639 for the control group (GroupB), respectively. The results indicate that the students from both groups had the same knowledge level before participation in the learning phase.

Table 1. Statistical analyses of pre-test and post-test results.

	Group	N	Mean	Standard Deviation
Pre-test	GroupA	72	4.201	0.540
	GroupB	72	4.368	0.639
Post-test	GroupA	72	6.750	0.745
	GroupB	72	8.090	0.983

After that, the learning phase took place and the students from each group were asked to study for a period of five weeks in the scenario of their group. After the end of the five-week phase, a post-test evaluation was performed. Specifically, all the students took a post-test that consisted again of multiple-choice questions and were of the same difficulty as the ones of the pre-test. The students were given again the same time (25 min) to complete the post-test.

The post-test results are illustrated in Table 2, and show that Levene's test validates the equality of the variances of the two groups. For the pre-test is calculated as F = 8.514, $p = 0.005$ and for the post-test F = 14.969, $p = 0.000$. The results indicate that there are clear differences in the mean performances of the students from the two groups on the post-test ($p = 0.000 < 0.05$). Specifically, p-value < 0.05 is considered statistically significant. The results of the study point out that after controlling for initial quantitative ability, the differences are statistically significantly different in the post-test scores for the two groups of the study. Therefore, it can be concluded that students from GroupB gave more correct answers than students from GroupA and that students from GroupB learned better than the students from GroupA. The results show that the boost of the performance of the students from GroupA was approximately 37.7% while the performance of the students from GroupB was 46%.

Table 2. Analyses of pre-test and post-test.

Equality of Variance		Levene's Test for Equality of Variances		*t*-Test for Mean				
		F	**Sig.**	**t**	**df**	**Sig.(2-Tailed)**	**MD**	**95% Confidence Interval of the Difference Lower, Upper**
Pre-Test	Equal	8.514	0.004	−1.759	142	0.081	−0.174	−0.368, 0.021
	Unequal			−1.759	138.231	0.081	−0.174	−0.368, 0.021
Post-Test	Equal	14.969	0.000	−9.214	142	0.000	−1.340	−1.627, −1.052
	Unequal			−9.214	132.377	0.000	−1.340	−1.628, −1.052

After the completion of the experiment that lasted five weeks, the students from the two groups were asked to fill in two questionnaires, which were the System Usability Scale (SUS) questionnaire [32] and a Likert-scale questionnaire. The purpose of these two instruments was to assess learners' opinions about the virtual environment, the embodied pedagogical agents, and their overall learning experience. The first questionnaire that students were asked to fill in was a five-point Likert scale questionnaire that asked students to express their agreement with a set of statements. In total, there were 10 questions based on the Likert scale (1: Not at all, 5: Very much), and the results of which are illustrated in Table 3. The second questionnaire that students were asked to fill in was the System Usability Scale (SUS) that was used for assessing the usability of the environment. The SUS questionnaire was employed for its short length and ease to answer. The ten questions were organized into two groups (positive and negative) and participants were asked to rate them on a five-point scale ranging from strongly disagree to strongly agree. The final score of the SUS is a number from 0 to 100 and it can be easily interpreted. SUS is, in general, a robust way to evaluate the usability of a system, even when there is a limited sample size available. An overall SUS score over 85 indicates that the system is highly usable, a score from 70 to 85 shows that the system is good to excellent, a score from 50 to 70 indicates that the system needs improvements while a score below 50 indicates that the system is unacceptable [33].

Regarding the reliability of the questionnaires and in order to derive secure conclusions from the questionnaire data, Cronbach's alpha [34] was calculated. The Cronbach's alpha metric was calculated to be 0.78 and 0.80 thus, pointing out a high reliability score. Hence, strong and secure conclusions can be drawn. In the following tables, the results of the questionnaires of the two groups are illustrated.

Table 3. Likert scale questionnaire results.

Question	GroupA			GroupB		
	Disagree/Strongly Disagree	Neutral	Agree/Strongly Agree	Disagree/Strongly Disagree	Neutral	Agree/Strongly Agree
I enjoyed using the 3D virtual reality environment	2.78%	34.72%	62.50%	2.78%	20.83%	76.39%
The assistance during the learning activities was helpful and assisted me.	5.56%	20.83%	73.61%	4.17%	15.28%	80.56%
I feel comfortable and confident during the learning activities.	4.17%	19.44%	76.39%	2.78%	12.50%	84.72%
The learning activities made me more active in the activities.	4.17%	13.89%	81.94%	4.17%	15.28%	80.56%
The learning activities increase my motivation.	4.17%	16.67%	79.17%	2.78%	13.89%	83.33%
The learning activities enhance my engagement.	5.56%	13.89%	80.56%	4.17%	11.11%	84.72%
The learning activities enhance my learning interest.	5.56%	12.50%	81.94%	4.17%	9.72%	86.11%
The learning activities enhance my cooperation with my peers	5.56%	11.11%	83.33%	4.17%	11.11%	84.72%
I recommend the 3D virtual reality environment to other classmates and to be integrated into the course curriculum.	5.56%	12.50%	81.94%	4.17%	15.28%	80.56%
Please rate you overall learning experience	6.94%	8.33%	84.72%	5.56%	12.50%	81.94%

The answers of the two groups show that students from GroupB, who studied in the second scenario, had a better learning experience. The majority of them enjoyed more their interaction with the educational environment and also had a better opinion about the training activities. The analyses show that GroupB considered the learning activities with the companion of the embodied pedagogical agents more attractive, which in turn, enhanced their interest and motivation in studying, and thus their engagement with the activities and the course (84.72% vs. 80.56%). What is more, GroupB also stated that they felt to be more confident during the training activities (84.72 % vs. 76.39%). The SUS questionnaires point out that all students had a good experience of the environment's usability and the pedagogical agents as learning companions. The GroupA score was 72, while the score of GroupB was 79, which shows that GroupB had a better learning experience in terms of interaction with the 3D virtual world environment and the pedagogical agents.

Another analysis concerns the examination of students' behavior in the virtual environment. We examined and compared the actions and the behavior of the two groups, and learning metrics were calculated as presented and explained in Table 4.

Table 4. Analysis of the students' actions.

Metric	GroupA	GroupB
Time spent studying in the AVARES 3D virtual world environment	33.33 (hours)	39.25 (hours)
Mean value of students performance in the system's training activities and exercises	5.1/10	6.2/10

The results were very interesting and encouraging and revealed that the embodied pedagogical agents in the second scenario provided students with greater and more intense support during their study. An interesting metric was the time that students spent studying in the system. In the second scenario, the embodied pedagogical agents assisted students in getting higher levels of engagement, as seen from the longer study hours. Another interesting aspect concerns the students from the second scenario who had a better learning experience and got better scores at the exercises. These scores concern the self-evaluation exercises that were multiple choice questions in the virtual environment.

Indeed, students from GroupB reported better performance in these tests (6.2/10 vs. 5.1/10), something that indicates that students from GroupB studied longer hours and learned more efficiently as well as had a better understanding of the course's aspects and topics.

5. Discussion

The experimental study revealed interesting findings and shed light on the effectiveness of virtual embodied pedagogical agents. The first hypothesis concerns the examination of the agents on students' learning experience and assumes that the agents improve the learning experience of the students. In this regard, the results of the experimental study point out that the overall learning experience of the students is improved when they learn in the virtual environment with the use of pedagogical agents that accompany them during their study. The results of the SUS questionnaires indicate that students have better interaction with the virtual environment and better experience towards the environment's usability when agents were employed as learning companions (72 score for GroupB vs. 79 score for GroupA). Moreover, the results of the Likert-scale questionnaires revealed that agents do improve the learning experience of the students (84.72% for GroupB vs. 81.94% for GroupA), their learning interest (76.39% for GroupB vs. 62.50% for GroupA) as well as their enjoyment (86.11% for GroupB vs. 81.94% for GroupA). The second hypothesis concerns the examination of the embodied pedagogical agents on students' performance and assumes that the agents improve students' performance and comprehension in virtual world educational environments. In this regard, the results of the experimental study reveal that the performance and the knowledge construction of the students are improved with the use of embodied pedagogical agents that accompany them during their study. Specifically, the pre-test, post-test results show that students learned and comprehend better the various concepts when agents are employed and accompany students during their study. The Levene's test validates the equality of the variances of the two groups. For the pre-test is calculated as $F = 8.514$, $p = 0.005$ and for the post-test $F = 14.969$, $p = 0.000$. The results indicate that there are clear differences in the mean performances of the students from the two groups on the post-test ($p = 0.000 < 0.05$) pointing out that students from GroupB learned better and deeper, reporting improved performance and better knowledge construction. Finally, the third hypothesis concerns the examination of the embodied pedagogical agents on students' cooperation and assumes that the agents enhance students' cooperation and communication with their peers. In this regard, the results of the experimental study reveal that the agents can improve cooperation among the students and can provide means for closer and more efficient cooperation. Moreover, the students' engagement with learning activities is enhanced when agents were employed as learning companions (84.72% for GroupB vs. 80.56% for GroupA).

The results of the study point out the important role that agents can play in virtual reality educational environments and their great impact on students' learning. The main condition for the efficient integration of agents in virtual reality educational environments concerns the actual involvement of the agents in the learning activities, and the accompany of students by standing near them during the activities. These conditions are substantiated to be highly beneficial for students' learning. The employment of pedagogical agents can have a great impact on students' learning experience and improve their engagement in learning activities, their cooperation with their peers, and most of all, their knowledge construction and performance.

6. Conclusions

Over the last years, the successful integration of virtual reality in distance education contexts has led to the development of various frameworks related to the virtual learning approach. 3D virtual worlds are an integral part of the landscape of education and demonstrate novel learning possibilities that can open new directions in education. An important aspect of virtual worlds relates to the intelligent, embodied pedagogical agents that are employed to enhance the interaction with students and improve their overall learning experience. The proper design and integration of embodied pedagogical agents in virtual environments are necessary and highly desirable. The purpose of this article is to examine the learning effectiveness that the embodied pedagogical agents have on students' learning experience, engagement and knowledge construction in 3D virtual world educational environments. Moreover, it examines the role of the agents as learning companions and investigates the effects on the learning outcomes of students and performance. We examine how students perceive the role of the pedagogical agents as learning companions during game-based scenarios and the effect that their assistance has on students' engagement and learning. A concrete evaluation was performed in AVARES 3D virtual world, which is dedicated to topics related to environmental engineering and the generation of energy from renewable sources. Students from our university studied in the 3D virtual world and participated in a wide spectrum of gamified learning procedures under different conditions and situations in terms of feedback, guidance, and presence of embodied pedagogical agents. The results of the study point out that the presence and the behavior of the embodied pedagogical agents can have a substantial impact on students' learning, improve their knowledge construction and increase their engagement and overall learning experience.

The present study draws some directions that future work could examine. First a direction for future work could examine how the appearance of the embodied pedagogical agents affects students learning. Specifically, in future work, we plan to design agents that resemble notable scientists (e.g., Albert Einstein) and assess the way that the appearance of the agents affects students learning experience. Moreover, another direction for future work concerns the examination of the correlation between the students' study time in the virtual world environment and their performance with the aim to analyze and specify proper learning paths and flows. This concerns the main direction that future work could examine.

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