Learner Experience in Hybrid Virtual Worlds: Interacting with Pedagogical Agents

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Abstract: Studies related to the Virtual Learning approach are conducted almost exclusively in Distance Learning contexts and focus on the development of frameworks or taxonomies that classify the different ways of teaching and learning. Researchers may be dealing with the topic of interactivity but mainly focusing on the interactions that take place within the virtual world. However, in non-distance learning contexts, where students not only share the virtual but also the physical space, different types of interplay can be observed. In this paper, we classify these 'hybrid' interactions and further correlate them with the impact that the instructional design decisions have on motivation and engagement. In particular, a series of experiments were conducted in the context of different Hybrid Virtual Learning units, with Computer Science and Technology students participating in the study, whilst, the chosen instructional design approach included the employment of different Pedagogical Agents who aimed at increasing the incentives for interaction and therefore, engagement. The conclusions provide suggestions and guidelines to educators and instructional designers who wish to offer interactive and engaging learning activities to their students.

1 INTRODUCTION

According to Konstantinidis et al. (2009), in Hybrid Virtual Learning (HVL) contexts, learning becomes more student-oriented and cooperative, whilst teaching is more interactive and rewarding. As HVL setup we define the context in which students are co-present and interact simultaneously in both environments, thus receiving stimuli related to the learning material from both directions.

Fernández-Gallego et al. (2013) stress the importance of interactions in the learning activities, whilst Dillenbourg et al. (2002) underline the lack of understanding of how to develop interactions for different learning objectives. Nevertheless, there is no record of any attempts to introduce taxonomies and frameworks that map and evaluate them, especially in HVL.

The studies that discuss interactions holistically (i.e. both in the physical classroom and the virtual world), report findings that have been derived from experiments which included the use of external hardware devices such as Oculus Rift, HTC Vive and so on (Klompmaker et al., 2013; Kronqvist et al., 2016). However, such devices might not be available to all educators/institutions. Therefore, following the common practice route to integrate the outcomes of studies which have been performed in mixed/augmented reality contexts in a strictly desktop-based HVL model, would be a far-fetched practice.

Ultimately, disregarding partly or even completely the network of interactions that is developed between the 'real' and the 'virtual' world simultaneously, diminishes or even dismisses the essence of the HVL approach, as well as restricts educators and instructional designers from reaching its maximum potential. Even more so after considering the lack of a common taxonomy for describing and classifying the types of interactions that take place in HVL contexts and their impact on learner engagement.

The main idea of this study is that interactions in virtual worlds, which have been modified to cover educational needs, can enhance the levels of learner engagement. Respectively, the interactions that take place in the physical classroom, related to the use of the virtual world, can assist in achieving that goal.

Considering the above, the main hypothesis of this study is formed, suggesting that interplay in HVL settings can increase learners' engagement with the virtual world, whilst instructional designers can further enhance and promote interactivity and,

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therefore, engagement with the learning material, through the use of different interventions.

2 RELATED WORK

The main principle of Agent-Based Learning refers to the enrichment of Virtual Learning Environments with autonomous agents so as to support the learning process (Heidig and Clarebout, 2011), improve the Human-Computer Interaction (HCI) experience, and increase learner engagement (Soliman and Guetl, 2010).

Even though, the potential of Artificial Intelligence (AI) is yet to be fully reached, the evolution of algorithms to develop AI agents has advanced and never ceases to evolve. Indeed, the idea of populating virtual worlds with agents (Non-Player Characters), as originally introduced by the game industry, has proven to be quite successful and has positively affected player experience (Umarov and Mozgovoy, 2014).

Employing Pedagogical Agents (PAs) in a virtual world can cover various needs and serve different purposes. For instance they can increase learners' motivation, engagement and self-efficacy, or moderate their frustration by supporting the learning process (Soliman and Guetl, 2010).

According to Garrido et al. (2010), the roles and the capabilities that the so-called agents may undertake, vary. This variety can be interpreted due to their utilisation in order to provide learners with additional instructional support and guidance through social interaction, interactive demonstrations, navigational guidance and attentional guiding or motivational boost (Rickel and Johnson, 2000; Terzidou and Tsiatsos, 2014; Zakharov et al., 2008).

However, the aforementioned viewpoints oppose the opinion of others who argue that PAs make no difference in the learning process and outcome (Perez and Solomon, 2005), as well as in learner motivation (Domagk, 2010). Garrido et al. (2010) even suggest that the presence of PAs may even distract learners from the learning content and objectives.

On the antipode, Clarebout and Elen (2006) noted some positive outcomes on retention, yet no difference in the knowledge transfer performance. Plant et al. (2009) identified a link between the gender of the agents and their impact on learner motivation, whilst Grivokostopoulou et al. (2018) concluded that the help and support offered to learners via the use of PAs greatly affected their engagement and improved their learning experiences.

3 MATERIALS AND METHODS

For the needs of this study, an institutionally hosted OpenSimulator virtual world—resourced from the University of Bedfordshire—was employed, whereas the available laboratory equipment was utilised in the context of weekly practical sessions. Students could also access the virtual world, outside the university network, using their personal computers. The purpose of this experiment was to examine the impact that different PAs have on the educational process, by offering support or mentoring as well as guidance and help with decision-making. The following PAs were utilised to attract students' interest and attention in different manners.

Jella Delta (Figure 1, left frame) had a human-like form, resembling the role of the instructor or educator, and was a conversational agent (chatbot) with knowledge-intensive and domain-specific question answering capabilities. Its role was to facilitate the learning process and support students by providing useful and meaningful answers to queries related to the virtual world.

Queen Kong (Figure 1, middle frame) was also a chatbot, though of a nonhuman type (ape), as an example of the contradictory content that virtual worlds can accommodate. Its role was to disorientate students by providing incorrect or 'nonsense' answers to their queries in a 'ludicrous' way.

Gizmo Gear (Figure 1, right frame) had a robot-like form, operating as a vendor. This agent was becoming interactive upon students' call and its role was to provide informational notecards (digital text-based notes), assign or suggest tasks and offer freebies (premade 3-D objects and scripts).

Figure 1: Snapshot of the PAs' appearance.

To reduce the impact of potential bias or preconceptions against this approach, no information related to the presence or the roles of the PAs were disclosed to students, so as to allow them to act naturally and discover their features as part of the exploration process.

3.1 Research Method

Research through qualitative research and, more precisely, the pedagogical observation method has a great number of advantages. The greatest one lies on the principles of 'immediate awareness' and 'direct cognition', i.e. the opportunity given to the researcher to have a 'direct look' at the actions taking place, without having to rely on second-hand accounts (Cohen et al., 2011). Moreover, observation is a very flexible form of unique data collection as it allows researchers to alter their focus, depending on the observed actions and behaviours. Finally, the method of observation allows the researcher to gather any necessary data, while the participants follow their own agenda unimpeded.

3.2 Data Collection

Participation in this study was voluntary and all students enrolled in the course were invited to participate. In other words, no filtering in terms of setting up 'standards' or specific criteria, such as age, gender, nationality, were made. Likewise, no particular selection, such as prior experience in similar platforms or generic interest in using or, thereof, not virtual worlds/games, was made either.

The content of the observation checklist was developed in accordance to the constructivist theoretical approach—as it emphasises the impact of interactions on the learning process—and is the outcome of a joint effort to blend the relevant literature (Rjaibi and Rabai, 2012; Zaharias, 2006) and authors' prior research experience in matters related to virtual worlds. Lastly, the collected data were analysed under the principles of the Grounded Theory approach (Strauss and Corbin, 1998) on the basis of which the following sub-categories were generated (see Sections 4.1.1-4.1.3 and 4.2.1-4.2.5).

4 RESULTS

The pedagogical observations aimed at discovering the meaning, dynamics and processes involved in the various actions and interactions that learners performed in both environments (i.e. physical classroom/virtual world). Students were observed during their practical sessions, using an observation checklist, whilst impromptu notes were also maintained. To increase the strength and the validity of the concluding remarks the experiment with the PAs was repeated with different cohorts (Table 1).

Table 1: Experiments' overview.

Academic level	Experiment code	Observation		Sample
		Weeks	Hours	
Undergraduate	A	4	12	17
Undergraduate	B	6	12	17
Postgraduate	C	4	8	16

4.1 Physical Classroom

4.1.1 Talking and Making Comments

The verbal interaction among the students was quite intense. Most of the comments or questions heard referred to the navigation tools, the avatars, and the objects' manipulation. Knowledge transfer among peers was present. Students tended to demonstrate their knowledge, discuss with their fellow students about the advice, suggestions, and information given by the teaching team, or even the knowledge they had acquired based on their personal research. Students did not hesitate to request their peers' help or feedback when needed. Nevertheless, student communication was not limited to issues related to the virtual world per se. They were exchanging information about available third-party software, useful in the context of the assignment, and even providing help and guidance to others on how to use it. In fact, it can even be said that this was the most intense cross-team peer-tutoring that students performed, as they were usually interacting almost exclusively with their team members. However, not all student conversations were strictly focused on the virtual world or the assignment. Students were also discussing matters unrelated to the virtual world yet related to other university units, or even completely unrelated to the university environment.

The verbal interaction between the students and the teaching team was almost as intense as the ones among students. Most of the comments or questions heard referred to the lab demonstrators regarding the general settings of the world, the navigation tools, the avatars, the objects' manipulation and programming. Moreover, students opted to discuss with the demonstrators issues regarding 3-D modeling, triggered by their concerns about the transition of their ideas to in-world development. Thus, brief conversations about third-party software, compatible with the virtual world were held, too. Approaching the end of each course, nearly all the groups wanted to perform an unofficial demonstration in order to get some 'last-minute' feedback. On the other hand, students who were struggling to deal even with the basic tools of the world wanted to find out more about the marking scheme and criteria—the 'passing' grade, in particular—of this assignment.

Students enjoying the use of the virtual world made positive comments about their emotional experience mainly when talking to each other. Exclamation comments were heard during the students' first contact with the virtual world. Some of them were excited for having the opportunity to learn more about this technology, while others expressed their enthusiasm about having the opportunity to acquire knowledge while engaging in activities that they perceived as games. Interestingly, by the end of the assignment, a student concluded that the use of a virtual world can open new horizons in product promotion.

On the other hand, negative comments about the virtual world were not absent either. There were students who, from the very beginning, questioned the reason for using a virtual world in the academic context. Generally, the technical malfunctions and the world's architecture attracted students' negative attention and was a source of negative comments. Students reported that the OpenSim technology was limiting their creativity and made them feel very insecure as to continuing working on this platform. Others expressed their disappointment or actually complained about some technical bugs. Moreover, in cases when latencies or freezes were present, due to the massive content and number of active scripts that was considerably high, students expressed their concern about potential future server crashes. Aside from that, the lack of an induction process was also a matter that caused students' disappointment. Those students, though recognising the potentials of the virtual world, intensively and repeatedly expressed their insecurity regarding the lack of theoretical knowledge on its technology.

4.1.2 Attitude towards the Virtual World

Students' attention was usually either on the lecturer's demonstration (whenever such occurred) or on their daily task/assignment. At the initial stage of each course of practical sessions, students' main task or goal was to learn more about the virtual world and familiarise themselves with its tools. As a result, they dedicated their time to exploring the world's content, researching the web and collecting information about the in-world tools and the programming language. As the classes were progressing, students were working on various tasks in order to ensure that all the assignment requirements had been fulfilled. Students were observed shifting between the virtual world, the web browser searching for information related to the in-world language and third-party programs. Switching interfaces was the main reason why students' attention and focus got distracted from the virtual world per se, though they kept being focused on their assignment.

On the other hand, there were cases when students were not necessarily absent-minded, though working on matters unrelated to the unit, dealing with matters related to other assignments, or even performing actions non-related to the university.

Regarding students' emotional experience, two basic categories could be identified: those who were enthusiastic, keen to learn more about this technology, and happy to explore its capabilities and those who were frustrated, disappointed and displeased with the world.

Students seemed to truly enjoy their time, be it during the moments of work, or the 'play-time'. The main source of pleasure and enjoyment was the verbal interaction that students had with each other. While exploring the in-world tools, the avatars attracted students' attention, as they offered them high levels of enjoyment and pleasure (especially during the appearance editing process) and triggered amusing conversations among them. Moreover, speaking loudly, making jokes or funny comments—while working on their project—was something that also observed as an indication of enjoyment and pleasure.

Technical issues, the nature of the assignment, or even the use of the virtual world in an academic context, worsened students' experience. Several students were displeased, or more precisely, disappointed about using a virtual environment for educational practices. Nonetheless, this attitude decreased as the sessions progressed. Another source of displeasure was the fast-paced nature of this project (time-wise), considering that they had to learn a programming language from scratch, as well as acquire the knowledge of how geometry works in 3-D environments. Even students who generally enjoyed the use of the virtual world experienced negative emotions, mainly frustration and anxiety, trying to meet the assignment's deadline. More apparent was the disappointment of those who were still struggling to deal with the world and its tools as the submission deadline was approaching. Those students kept questioning—with displeasure or even frustration—the virtual world's inclusion to the teaching curriculum. Lastly, what was also highlighted by students as displeasing was the harassing behaviour that some of them had in the virtual world, not only during the practical sessions but also outside them.

4.1.3 Student Identity and Avatar Identity

References related to avatars were infrequent. The person (1st, 2nd, 3rd, singular or plural) that the students were using when referring to their avatars depended mainly on the situation, as well as on the level of embodiment they had developed with their avatars and the virtual world. More often than not, students opted to use the first person when referring to their own avatars, less frequently the third, and rarely the second. Interestingly, only one reference to the avatar as an object ('it') was observed. Moreover, very few students engaged in role-play actions for a limited period of time in, an attempt to entertain themselves.

4.2 Virtual World

4.2.1 Talking and Making Comments (Chat)

When it comes to verbal interaction, face-to-face communication is the one mostly preferred. Nevertheless, in cases where this is not feasible, or low noise levels have to be maintained in the physical classroom, students tend to use the in-world chat tool to cover their needs. Indeed, at various times students were observed greeting each other, expressing their opinion, exchanging pieces of code, asking questions and discussing other matters university-related. Very rarely did students discuss matters non-related to the class or the university context. After reviewing the chat logs, it can be reported that the frequency of the internet slang words was fairly high. Equally high was the use of the words revealing exclamation. The only negative comments made were related to the OpenSim technology—the functions that were not implemented, in particular—and the short freezes or latencies of the server.

4.2.2 Nonverbal Communication

In-world nonverbal communication was scarce. Students with increased curiosity explored almost all the built-in secondary tools, including gestures. Students tested almost all animated moves of avatars from the gestures library to observe their function, without them covering any other particular need. Avatar gestures/animations were also used in order to 'tease' the lecturer's avatar or other students, especially when they were away from their keyboards. In very few situations, students did the opt to develop their own gestures, aiming to amuse themselves and their classmates. The use of emoticons, on the other hand, was as intense as the use of the chat tool. Almost every time that the chat tool was used, the text was accompanied by emoticons fit for the purpose.

4.2.3 Interactions with the World's Content

Content creation and exploration, use of the built-in tools, importation of 3-D models and textures from a third-party software, were the actions that monopolised students' attention. More often than not, the majority of students were at their workspaces, working focused on their task, with small intermediate breaks to explore the content of the world and interact with their fellow students. Students opted to use mainly their own creations checking their functionality, but they were also glancing at their classmates' ones while wandering in-world. Interestingly, some of the teams opted to enable the group function—which allows members to edit primitives and scripts developed by others—without, however, such an action being observed. The aforementioned actions or students' attitude towards the world cannot be judged in a negative way. In fact, it can even be considered as a good sign, considering that students simply worked on their task.

An action non-related to the world, yet related to the project, that was frequently observed, was the 3-D objects development which some students performed using third-party software. In particular, students developed textures or models, which they consequently imported in-world to alter the avatars' appearance or as part of their project. They were also looking for pre-made scripts online, importing and testing their functionality in-world, without, however, making any changes.

Students wandered around the world, from time to time, chasing their fellow students and performing 'childish'—one can say—actions. Even though students were having frequent breaks to perform actions non-related to their work, this did not prevent them from (at least) 'ticking off' the assignment's checklist boxes. Nevertheless, what did, in fact, negatively affect students' engagement was the disruptive or inappropriate behaviour that some students had towards others, in an attempt to ‘play with’ or ‘chase’ them. Indeed, when someone is over-focused on the task or struggling to deal with it, getting constantly disrupted by others can only have negative results, and this is where the teaching team should intervene.

Students’ attitude towards the PAs was mixed. One of the three cohorts of students (EC) was enthusiastic with them, especially at their first practical sessions. In particular, almost all of them had intense interactions with the vendor-NPC (Gizmo), reading through the information notecards, discussing the proposed suggestions for development, or even sharing the freebies that were randomly offered to them. Less intense, in terms of student numbers, but equally frequent was the interaction that students had with the tutor-NPC (Jella). Interestingly, one of them was even observed keeping digital copies of the in-world chat log of the NPC’s answers to his questions. Lastly, less intense and very infrequent was students’ interaction with the distractor-NPC, as they were not getting any meaningful answers to their queries.

Contrary to that, the other two cohorts of students had minimal interactions with the PAs. Only some of the students had very few interactions with all the NPCs, though only the tutor-NPC and the vendor-NPC were the ones who monopolised their interest and were acknowledged for their impact on the learning process. In any case, the lack of interaction between the students and the PAs is hard to be judged.

4.2.4 Student Identity and Avatar Identity

Almost all students had avatars with an even slightly modified appearance. Nevertheless, the short periods of time that most of them spent during the practical sessions to edit their avatars’ appearance or, in other words, the limited interest to perform such action during the practical sessions can be justified after considering that their main concern was to familiarise themselves with the world and its tools, and proceed with the development of their showcase infrastructure.

Nonetheless, some students had made very detailed modifications on their avatars’ appearance, in terms of both quality and quantity, creating unique outfits for them or turning them into ‘punks’, ‘rockers’, ‘robots’ and even ‘superheroes’. Interestingly, some of them had even used third-party software to import pre-made or self-made objects. This is, indeed, a good indication that students spent a considerable amount of their personal time, outside the practical session, to not only be in the virtual world but also work on their avatars’ appearance. Furthermore, it provides an insight of the way they opt to invest their time while being inside and outside the university classroom. Other students, however, had completely unmodified avatars, as this was a feature out of their personal interest.

A few students, those who invested considerable time modifying their avatars, engaged in role-play activities during their practical sessions. They were also observed refering to their avatars in the first person, an attitude which reveals that they were experiencing embodiment. Apart from those occasions, the references to the avatars were rare.

4.2.5 Willingness to Remain Online Longer

Students were fairly punctual to the schedule, entering the virtual world at the starting point of the session and remaining in-world until the end. However, at various times they were away from their avatars, or even coming on and off the virtual world, according to the needs of their team. In other occasions, when not all students’ online presence was mandatory, students went online to provide some hands-on support and additional feedback to their team members. That said, late log-ins and early log-outs were not rare occasions. Nevertheless, examining server logs and students’ progress between the sessions, it can be safely stated that they invested part of their time outside the university classroom.

5 DISCUSSION

The participating groups shown a positive attitude in relation to the impact that the rich network of interactions—both with the content and with others—had on their motivation to engage with the world and the learning activities. Nevertheless, that should not lead to the invalid conclusion that this approach was perfectly appropriate or suitable for all of them. Indeed, the most influential factors that affected learner engagement were: the alternative educational approach, which brought the technical and the social aspects together, learners’ curiosity about how programming can be done differently in such environments, and learners’ fascination to explore and work—either alone or along with others—on a new/alternative technological platform.

Table 2 maps the interactions that affected learner engagement in the context of the HVL approach.

Table 2: The taxonomy of interactions in the HVL setup.

		Virtual World	Classroom
High Engagement	Student-to-Student	❖ Verbal communication & emoticons ❖ Collaboration ❖ Experience of knowledge ❖ Source of enjoyment ❖ Peer-tutoring Peer-learning	❖ Verbal communication (project related) ❖ Collaboration ❖ Source of enjoyment ❖ Peer-tutoring Peer-learning
Low Engagement	Student-to-Student	❖ Nonverbal communication ❖ Griefing & misbehaviour	❖ Verbal communication (project unrelated)
Personality Related	Student-to-Student	❖ Avatars & embodiment ❖ Sense of presence	❖ Feelings' sharing
High Engagement	Student-to-World	❖ 3D modeling & programming ❖ Experience of knowledge ❖ Source of enjoyment ❖ Content exploration & use	❖ Positive prior experiences & beliefs
Low Engagement	Student-to-World	❖ Technical limitations & malfunctions	❖ Negative prior experiences/preconceptions ❖ Technical malfunctions Struggle with the technology
Personality Related	Student-to-World	❖ Avatars' appearance editing ❖ Sense of presence ❖ Pedagogical Agents	❖ Game-like environment ❖ Time/effort investment

The educational and technical support provided by the agents played an equally fundamental role on the type and frequency of interactions, though in a less diligent manner. In general, the different design elements of the NPCs offered a more personalised experience with diverse effects on learners' motivation and achievements. Indeed, by creatively combining the available resources (i.e. knowledge-pool of the chat-bots) and the instructional artefacts (i.e. freebies or advices), learners were enabled to materialise their ideas, develop their concepts and even share the acquired knowledge with others. Nevertheless, the motivational influence of the conversational NPCs—on the social interaction processes—seems to be moderate, besides their dynamic character and intersubjective nature. On the other hand, the presence of an NPC with goal-oriented characteristics (robot) influenced more positively the levels of awareness and contributed towards the knowledge construction and advancement.

6 CONCLUSION AND FUTURE DIRECTIONS

Even though Virtual Learning (VL) already counts for several decades of practice, the idea that underpins the HVL approach opened new educational horizons. Indeed, VL and HVL have different attributes and characteristics and thus, any conclusions drawn by research conducted in distance/VL contexts cannot easily be transferred to HVL setups.

In the context of this study, the initial hypothesis regarding the importance of examining interactions both in the virtual world and in the physical classroom, in conjunction with one another and not in isolation, has been validated and confirmed. Learners' simultaneous physical and virtual co-location broadened the network of interactions, eliminated the drawbacks and the weaknesses of each educational approach and enhanced their strengths. In fact, this is the essence of employing the HVL approach. In other words, the interactions not only in-world—which have been extensively investigated—but also in-class, should be considered as factors that affect learners' attitude and motivation towards learning, and influence their engagement with the virtual world and the educational activities, by extension.

In this experiment, the learners' interest was attracted almost exclusively by the PAs that could, at least, offer some kind of support towards their needs. On the other hand, the PA who aimed at disorientating or, at most, entertaining them met with a complete lack of attention. Thus, in order for a degree of desirable interaction with the PAs to be achieved, the essence of the PAs should be either an essential part of the educational process or, at least, correlated and fully incorporated in the learners' task. In any case, although such content might have limited influence on engagement, the presence of these entities can potentially increase the interactivity of the virtual world and thus, instructional designers are advised to provide learners with diverse opportunities for personalised tutoring through the utilisation of PAs.

However, the inability of conversational agents to regulate emotional responses makes the employment of such concepts problematic. Indeed, using PAs to deliver a fully personalised or optimal experience—especially in virtual worlds like OpenSim—becomes even more challenging, due to the inadequate nature of the technology to support such entities. Therefore, future work might further develop this platform or migrate on a different infrastructure that better supports the integration of AI algorithms for better tailored responses by the PAs. This might also allow for the accommodation of larger student cohorts, consequently facilitating cross-institutional student interaction.

REFERENCES

Clarebout, G., and Elen, J., 2006. Open Learning Environments and the Impact of Pedagogical Agents. *J. Educ. Comp. Res., 35*, 211–226.

Cohen, L., Manion, L., and Morrison, K., 2011. *Research methods in education*, Routledge. London, 7th edition.

Dillenbourg, P., Schneider, D. and Synteta, P., 2002. Virtual learning environments. In *3rd Hellenic Conf. Info. & Com. Tech. in Edu.* (pp. 3-18). Kastaniotis Editions, Greece.

Domagk, S., 2010. Do pedagogical agents facilitate learner motivation and learning outcomes? The role of the appeal of agent's appearance and voice. *J. Media Psychology, 22*(2), 82–95.

Fernández-Gallego, B., Lama, M., Vidal, J. C., and Mucientes, M., 2013. Learning Analytics Framework for Educational Virtual Worlds. *Procedia Comp. Sci. 25*, 443-447.

Garrido, P., Martinez, F. J., Guetl, C., and Plaza, I., 2010. Enhancing intelligent pedagogical agents in virtual worlds. In *Workshop Proc. 18th Int. Conf. on Comp. in Educ.* (pp. 11-18). Asia-Pacific Society for Computers in Education.

Grivokostopoulou, F., Paraskevas, M., Perikos, I., Nikolic, S., Kovas, K., and Hatzilygeroudis, I., 2018. Examining the Impact of Pedagogical Agents on Students Learning Experience in Virtual Worlds. In *2018 IEEE Int. Conf. on Teach., Ass., and Learn. for Eng. (TALE)* (pp. 602-607). IEEE.

Heidig, S., and Clarebout, G., 2011. Do pedagogical agents make a difference to student motivation and learning?. *J. Educ. Res. Rev., 6*(1), 27-54.

Klompmaker, F., Paelke, V., and Fischer, H., 2013. A Taxonomy-Based Approach towards NUI Interaction Design. In N. Streitz and C. Stephanidis (Eds.) *Distributed, Ambient, and Pervasive Interactions. Lecture Notes in Comp. Sci., 8028*. Springer, Berlin.

Konstantinidis, A., Tsiatsos, Th., and Pomportsis, A., 2009. Collaborative Virtual Learning Environments: Design and Evaluation. *Multimed. Tools and Apps., 44*(2), 279-304. Springer.

Kronqvist, A., Jokinen, J., and Rousi, R., 2016. Evaluating the Authenticity of Virtual Environments: Comparison of Three Devices. *Advances in Human-Computer Interaction, 2016*, 14 pages.

Perez, R., and Solomon, H., 2005. Effect of a Socratic Animated Agent on Student Performance in a Computer-Simulated Disassembly Process. *J. Educ. Multimedia and Hypermedia, 14*(1), 47–59.

Plant, E. A., Baylor, A. L., Doerr, C. E., and Rosenberg-Kima, R. B., 2009. Changing middle-school students' attitudes and performance regarding engineering with computer-based social models. *C&E, 53*, 209–215. Elsevier.

Rickel, J., and Johnson, W. L., 2000. Task-oriented collaboration with embodied agents in virtual worlds. In J. Cassell, J. Sullivan, S. Prevost and E. Churchill (Eds.) *Embodied conversational agents* (pp. 95-122). MIT Press. Cambridge.

Rjaibi, N., and Rabai, L. B. A., 2012. Modeling The Assessment of Quality Online Course: An empirical Investigation of Key Factors Affecting Learner's Satisfaction. *IEEE Tech. and Eng. Educ., 7*(1), 6-13. IEEE.

Soliman, M., and Guetl, C., 2010. Intelligent pedagogical agents in immersive virtual learning environments: A review. In *Proc. 33rd Int. Convention on Info. and Com. Tech., Electronics and Microelectronics* (pp. 827-832). IEEE.

Strauss, A. and Corbin, J., 1998. *Basics of qualitative research: Techniques and procedures for developing grounded theory*, Sage Publications. Thousand Oaks, CA: 2nd edition.

Terzidou, T., and Tsiatsos, Th., 2014. The impact of pedagogical agents in 3D collaborative serious games. In *Proc. IEEE Global Eng. Educ. Conf.* (pp. 1-8). IEEE.

Umarov, I., and Mozgovoy, M., 2014. Creating Believable and Effective AI Agents for Games and Simulations: Reviews and Case Study. In *Contemporary Advancements in Information Technology Development in Dynamic Environments* (pp. 33-57), IGI Global. Hershey, PA.

Zaharias, P., 2006. A usability evaluation method for e-learning: focus on motivation to learn. In *CHI'06 Extended Abstracts on Human Factors in Comp. Sys.* (pp. 1571-1576). ACM.

Zakharov, K., Mitrovic, A., and Johnston, L., 2008. Towards emotionally-intelligent pedagogical agents. In *Int. Conf. on Intelligent Tutoring Systems* (pp. 19-28). Springer.