Pedagogical Agents in Virtual Reality for Training of Biomedical Engineering Students

Ersilia Vallefuoco[a], Elisabetta Ponticelli, Alessandro Pepino[b] and Francesco Amato[c]
Department of Electrical Engineering and Information Technology, University of Naples Federico II,

{*ersilia.vallefuoco, pepino, framato*}*@unina.it, eli.ponticelli@studenti.unina.it*

Keywords: Pedagogical Agent, Virtual Agent, Conversational Agent, eXtended Reality, Virtual Reality, Engineering Education, Simulation, Experiential Learning.

Abstract: Technological advancements have enhanced the development of pedagogical agents (PAs) to support the learning processes. The present work describes a new application of a PA in a virtual reality (VR) environment for the education of students in biomedical engineering. The PA, represented by a virtual physician, allows the student to analyze the healthcare system in an interactive way, favoring the acquisition of professional skills. A preliminary test was performed with a small sample size. The results show good usability and credibility, with responses from participants revealing that the PA is effective for reflection on complex healthcare systems. Future enhancement will be done on the PA's nonverbal cues, followed by full integration into virtual environments to improve user engagement and realism.

1 INTRODUCTION

Recent technological advances, particularly following the COVID-19 pandemic, have facilitated the adoption of new digital learning applications in higher education (Alenezi, 2023). Among these, pedagogical agents (PAs) have emerged as innovative educational tools that enhance teaching and learning processes (Lane and Schroeder, 2022). A PA - also known as an embodied conversational agent, an intelligent virtual agent, and a virtual human - can be broadly defined as a virtual character that can engage and communicate with users for instructional purposes (Dai et al., 2022). By leveraging artificial intelligence (AI) and natural language processing, PAs can interact with users through verbal and nonverbal interactions, while also processing inputs from multiple sensors (Lugrin et al., 2022).

Previous studies (Heidig and Clarebout, 2011; Zhang et al., 2024; Davis et al., 2023) have shown that PAs can provide personalized learning experiences in which they can present information, support learners like a tutor, monitor their activities, and improve their motivation (Apoki et al., 2022). Additionally, communication and social strategies can occur when learners interact with a PA (Sikström et al., 2022; Schroeder et al., 2013), especially when the agent has a human-like appearance and uses nonverbal cues (Tao et al., 2022; Septiana et al., 2024).

Technologies of virtual reality (VR) can support the development of realistic PAs, not only in terms of appearance but also in terms of believability and social interaction (Grivokostopoulou et al., 2020). The possibility for users to share a virtual physical space with the PA establishes a social context for interaction, enabling also collaboration and increasing the physical perception of the agent's social presence (Guimarães et al., 2020). People recognize the social space of the virtual agent and adjust their interpersonal space based on the agent's gender and behavior (Kyrlitsias and Michael-Grigoriou, 2022). Moreover, previous research (Bergmann et al., 2015; Nuñez et al., 2023) has shown that adaptation mechanisms presented in human-human interaction (e.g., lexical, syntactic, and semantic alignment) can also be reproduced in interactions with virtual agents. Enriching VR environments with a PA creates an interactive social learning experience that can significantly foster learning (Petersen et al., 2021).

The integration of PAs in educational activities varies significantly depending on the higher education context. For instance, (Chheang et al., 2024) pro-

[a] https://orcid.org/0000-0003-3952-1500
[b] https://orcid.org/0000-0001-6434-5145
[c] https://orcid.org/0000-0002-9053-3139

Vallefuoco, E., Ponticelli, E., Pepino, A. and Amato, F.
Pedagogical Agents in Virtual Reality for Training of Biomedical Engineering Students.
DOI: 10.5220/0013502400003932

In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 1*, pages 915-920
ISBN: 978-989-758-746-7; ISSN: 2184-5026

posed a VR application with a PA for medical education. The PA, developed using ChatGPT and embodied virtual characters, provides guidance and assistance in learning human anatomy. Similarly, another study (Dai et al., 2024) provided a VR platform to develop teaching skills. The AI-powered PAs simulate student behaviors and facilitate interactive and reflective teaching practices. (Grivokostopoulou et al., 2020) investigated the effectiveness of an embodied PA in virtual learning environments for the learning of environmental engineering and renewable energy production. The findings reveal that the agent enhanced the learning experience, increased student engagement, and improved knowledge acquisition and performance.

This study is part of an ongoing innovation effort within the biomedical engineering (BME) program at the University of Naples Federico II, which is working to integrate new simulation tools aimed at providing experiential educational opportunities. In particular, the current study presents an example application of a VR-based PA in BME education. The proposed application aims to deliver meaningful learning experiences for BME students, focusing on the development of soft skills. A critical aspect of BME education is preparing students for multidisciplinary roles that require effective interaction and collaboration with diverse healthcare professionals (Montesinos et al., 2023). The proposed PA has been developed and integrated into the practical activities of the "Healthcare Organization Models" course, part of the BME program at the University of Naples Federico II. The virtual PA is accessible through the course's Moodle platform via a web application. A preliminary test was conducted to identify potential usability issues and explore how learners perceive the PA.

2 METHODS

The course "Healthcare Organization Models", offered in the Masters' program of BME at the University of Naples Federico II, is designed to provide knowledge and develop skills needed to understand and manage the services and structures of healthcare systems. At the end of the course, students will be able to analyze complex healthcare organization models, measure their performance, and propose solutions to optimize them via simulation tools.

However, analyzing healthcare organizational systems requires continuous interaction with various healthcare professionals to gather and evaluate information and/or data and then propose potential improvements. For this interaction to be effective, biomedical engineers need soft skills that enable them to ask the right questions and identify key issues and critical points within the system.

Based on these considerations, an instructional activity was designed using a PA in a VR environment to train students' soft skills, especially communication, in collecting information and data necessary for analyzing healthcare processes. The activity was structured to be conducted both in the classroom and at home through the course's Moodle platform. In the classroom, the instructor and students interact with the PA to analyze and model a healthcare system. Following the lesson, students can independently interact with the virtual agent to practice and develop their soft skills further, applying them to the analysis and modeling of other healthcare systems.

2.1 VR Application

The main objective of the proposed application is to train BME students to interact effectively with health professionals. The proposal is aimed at Italian BME master students.

The VR scenario has been designed to simulate a hospital doctor's office. As shown in Fig. 1, the room has a rectangular layout and is furnished with objects typically found in a real office. All 3D models of the objects were downloaded from (Sketchfab, 2024). The players can move freely using the directional keys on the keyboard, and they can interact with the PA by typing text from the keyboard into the chat or vocally pressing the T key.

The VR application has been developed as a web application and is accessible via URL on Moodle's platform. In particular, (PlayCanvas, 2024) was used as a WebGL game engine, with the integration of WebXR, to develop the virtual environment, whereas (Convai, 2024) was used to implement the PA. Convai facilitates the development of a virtual agent, allowing for the customization of its narrative, personality, knowledge base, and large language models (LLMs).

Using the character description, a brief background on the character's story, personality traits, and distinctive features was provided. More specifically, the PA is a 40-year-old internist physician with 10 years of experience in the Internal Medicine Department of the Antonio Cardarelli Hospital in Naples. The agent is female and is named Sofia (Fig. 2). Sofia's body was created using (Ready Player Me, 2024) and is dressed as a doctor. Sofia has been designed to provide information exclusively about the activities, services, and examinations in her department and hospital. Hence, users can ask questions related to these topics. If inquiries are made about un-

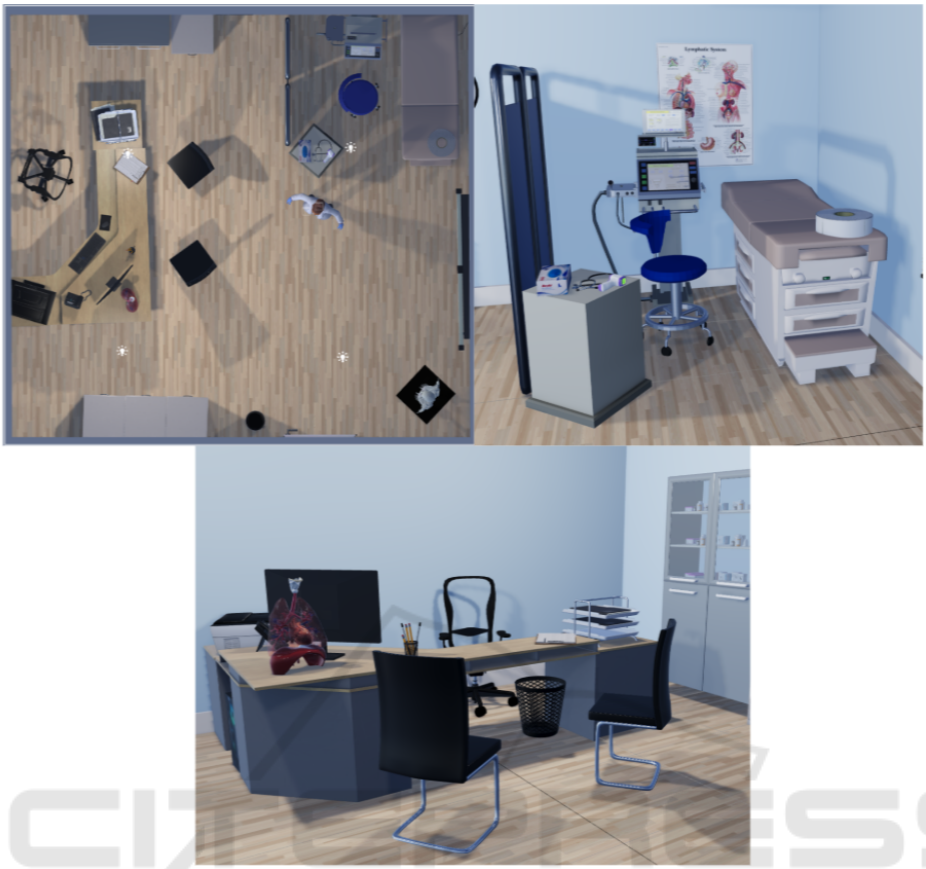

Figure 1: The virtual environment designed for the VR application. The top view (top left) provides an overview of the layout, while detailed views (top right and bottom) showcase specific areas, including a medical examination corner and the physician's desk setup for consultations.

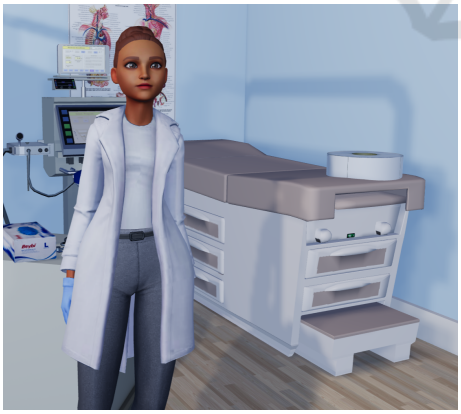

Figure 2: The developed pedagogical agent. The figure illustrates Sofia, a virtual internist physician.

related subjects, Sofia's standard response is: "Sorry, but I can't help you".

Regarding personality, Fig. 3 shows the settings of personality traits. The speaking style was set to be formal and knowledgeable, with examples of possible sentences. The language was set to Italian and a default multilingual voice from Convai was used. For the LLM, the Claude 3-5-Sonnet was chosen after comparing several proposed models, specifically GPT-4o and Gemini-Pro. The comparison was made using the same set of questions, and the authors evaluated the accuracy and relevance of the answers for each LLM model. Filters were enabled to prevent potential violations. In addition, additional knowledge in the form of text files was integrated into the agent's knowledge base. These cover the topics of services, activities, and data of Sofia's department and hospital.

After the design phase, conversation training sessions were conducted with the PA to identify and correct any deviations or errors in the interaction. The authors conducted this training phase individually.

3 PRELIMINARY TEST

An initial exploratory evaluation was conducted to gather preliminary feedback on the VR application and users' perceptions of the PA. 7 BME students

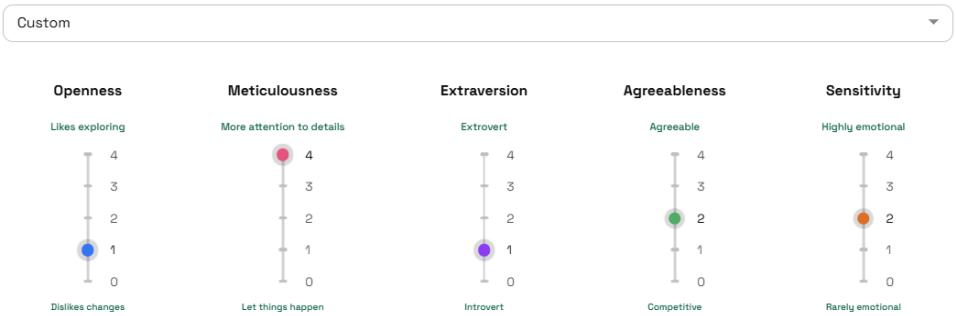

Figure 3: Personality trait settings of the pedagogical agent. The figure shows the personality customization of the virtual agent, across five dimensions: Openness, Meticulousness, Extraversion, Agreeableness, and Sensitivity.

(6 females and 1 male) were recruited by posting an announcement on the latest Moodle course. None of the participants had previous experience with PAs in VR, but 4 reported having experience with VR games. The announcement provided participants with comprehensive information about the study's purpose, data collection procedures, and privacy protection measures. All participants provided their consent before participating in the test.

The test was conducted as an unmoderated remote test (Black and Abrams, 2018), where participants received clear instructions and task guidelines for using the application. Specifically, they accessed the VR application through Moodle and used their personal computers to run the web application. The interaction task required participants to ask the agent questions useful for analyzing and modeling a healthcare process, with interaction limited to 10 questions. At the end, participants completed two different questionnaires: the System Usability Scale (SUS) (Brooke et al., 1996) and the Agent Persona Instrument (API) (Baylor and Ryu, 2003; Ryu and Baylor, 2005). The SUS is a 5-point Likert scale designed to assess various usability aspects, including ease of use, efficiency, and user confidence in the system. The API is used to investigate how the PA is perceived by learners. The instrument was organized into four dimensions: facilitation of learning, credible, human-like, and engaging. Additionally, we included an open-ended section where participants could freely express their opinions and provide feedback on their experiences.

The mean score for SUS was 92.5 (SD = 5.2). The results of the API are summarized in Table 1.

Table 1: Results of the Agent Persona Instrument (API). The table presents the mean scores for each API domain.

API	Mean score (SD)
Facilitating Learning	4.3 (0.6)
Credible	4.6 (0.2)
Human-like	2.8 (0.8)
Engaging	3.1 (0.8)

Participants reported no problems during the test session, except for one session where the agent stopped working. It was necessary to close the web application to restore proper functionality.

In general, the questions asked by users were varied and touched on different aspects of healthcare processes. Topics ranged from hospital activities to logistical and structural aspects of the hospital to potential critical issues. In all cases, the PA responded accurately. In particular, Sofia provided general estimates of wait times and patient flow between activities when requested. The PA also provided possible solutions to critical health issues and a general estimate of resources and beds in its department and the hospital. Critical issues identified by the PA included a lack of beds relative to the number of patients, excessive wait times for specialized tests, and a lack of staff.

4 DISCUSSION AND CONCLUSION

Several studies (Dai et al., 2022; Zhang et al., 2024) have shown that PAs can be used to support and guide learners during instructional activities. VR technologies can enhance users' sense of agency and trust as well as increase their motivation and engagement (Lugrin et al., 2022; Chiou et al., 2020).

In the present study, we propose an application of embodied PA in a VR environment. The application is designed to provide a training tool for BME students to develop skills for interacting with healthcare professionals. The PA is a physician that users can question to collect data and information useful for analyzing a healthcare process. The PA was designed to be used via web application in a specific course within the Master's program at the University of Naples Federico II. A preliminary test was conducted to investigate the users' perception of the VR application and the PA.

All participants indicated an excellent level of usability (SUS score > 80.5): the application was user-friendly and easy to use. The API results showed that the PA encouraged participants to reflect and focus on the complexity of healthcare processes (the central topic of their discussion). In addition, most participants indicated that the PA was interesting and knowledgeable. As expected based on the PA design, the level of humanness was low; in fact, participants recognized that the PA did not exhibit particular emotions and was neither friendly nor entertaining.

These results aligned with participants' feedback, which was generally positive, particularly regarding the agent's credibility. For instance, one participant stated: "Although the agent did not have a realistic appearance, its behavior was in line with its role". Another participant indicated the usefulness of the PA in instructional activities: "Very valuable tool that could provide good support to the student in studying and developing a simulation model for the management of healthcare organizational exam".

To our knowledge, this is the first study to explore the use of a virtual PA for training BME students. Consistent with previous research (Petersen et al., 2021; Zhang et al., 2024; Kyrlitsias and Michael-Grigoriou, 2022), our findings highlight the potential of VR-based PAs in creating dynamic and interactive learning environments. BME students traditionally face limited opportunities to develop communication skills needed for interaction with healthcare professionals (Montesinos et al., 2023), PAs not only provide a valuable platform for communication skill training but also offer a unique avenue for students to explore and acquire new knowledge through interactive experiences. Following previous studies (Chheang et al., 2024; Grivokostopoulou et al., 2020), participants responded positively to the application, emphasizing its engaging nature, real-time feedback capabilities, and the flexibility to practice interviews at their convenience. Another important aspect of the proposed system is its integration with Moodle. This integration makes the system particularly valuable for supporting open-source initiatives and open educational resources.

Despite the promising results, some limitations should be acknowledged. First, the study involved a small sample size, limiting the generalization of the findings. Future research should conduct larger-scale evaluations to validate the effectiveness of the PA. Second, while the PA provided accurate and structured responses, its limited nonverbal cues (e.g., body gestures, lip synchronization) affected perceived engagement. Future improvements could enhance the agent's interactive cues and fidelity to improve the learning experience (Nuñez et al., 2023). Moreover, as a future development, we aim to integrate the application into a fully immersive virtual environment, further increasing engagement and realism in the learning experience. Furthermore, recognizing the current limitations of the agent's knowledge base, we plan to expand its available data to improve the accuracy and comprehensiveness of its responses.

REFERENCES

Alenezi, M. (2023). Digital learning and digital institution in higher education. *Education Sciences*, 13(1):88.

Apoki, U. C., Hussein, A. M. A., Al-Chalabi, H. K. M., Badica, C., and Mocanu, M. L. (2022). The role of pedagogical agents in personalised adaptive learning: A review. *Sustainability*, 14(11):6442.

Baylor, A. and Ryu, J. (2003). The api (agent persona instrument) for assessing pedagogical agent persona. In *EdMedia+ innovate learning*, pages 448–451. Association for the Advancement of Computing in Education (AACE).

Bergmann, K., Branigan, H. P., and Kopp, S. (2015). Exploring the alignment space–lexical and gestural alignment with real and virtual humans. *Frontiers in ICT*, 2:7.

Black, J. and Abrams, M. (2018). Remote usability testing. *The Wiley Handbook of Human Computer Interaction*, 1:277–297.

Brooke, J. et al. (1996). Sus-a quick and dirty usability scale. *Usability evaluation in industry*, 189(194):4–7.

Chheang, V., Sharmin, S., Márquez-Hernández, R., Patel, M., Rajasekaran, D., Caulfield, G., Kiafar, B., Li, J., Kullu, P., and Barmaki, R. L. (2024). Towards anatomy education with generative ai-based virtual assistants in immersive virtual reality environments. In *2024 IEEE International Conference on Artificial Intelligence and eXtended and Virtual Reality (AIxVR)*, pages 21–30. IEEE.

Chiou, E. K., Schroeder, N. L., and Craig, S. D. (2020). How we trust, perceive, and learn from virtual humans: The influence of voice quality. *Computers & Education*, 146:103756.

Convai (2024). https://www.convai.com, Accessed Jan. 25, 2025.

Dai, C.-P., Ke, F., Zhang, N., Barrett, A., West, L., Bhowmik, S., Southerland, S. A., and Yuan, X. (2024). Designing conversational agents to support student teacher learning in virtual reality simulation: a case study. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*, pages 1–8.

Dai, L., Jung, M. M., Postma, M., and Louwerse, M. M. (2022). A systematic review of pedagogical agent research: Similarities, differences and unexplored aspects. *Computers & Education*, 190:104607.

Davis, R. O., Park, T., and Vincent, J. (2023). A meta-analytic review on embodied pedagogical agent de-

sign and testing formats. *Journal of Educational Computing Research*, 61(1):30–67.

Grivokostopoulou, F., Kovas, K., and Perikos, I. (2020). The effectiveness of embodied pedagogical agents and their impact on students learning in virtual worlds. *Applied Sciences*, 10(5):1739.

Guimarães, M., Prada, R., Santos, P. A., Dias, J., Jhala, A., and Mascarenhas, S. (2020). The impact of virtual reality in the social presence of a virtual agent. In *Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents*, pages 1–8.

Heidig, S. and Clarebout, G. (2011). Do pedagogical agents make a difference to student motivation and learning? *Educational Research Review*, 6(1):27–54.

Kyrlitsias, C. and Michael-Grigoriou, D. (2022). Social interaction with agents and avatars in immersive virtual environments: A survey. *Frontiers in Virtual Reality*, 2:786665.

Lane, H. C. and Schroeder, N. L. (2022). Pedagogical agents. In *The Handbook on Socially Interactive Agents: 20 years of Research on Embodied Conversational Agents, Intelligent Virtual Agents, and Social Robotics Volume 2: Interactivity, Platforms, Application*, pages 307–330.

Lugrin, B., Pelachaud, C., and Traum, D. (2022). *The Handbook on Socially Interactive Agents: 20 years of Research on Embodied Conversational Agents, Intelligent Virtual Agents, and Social Robotics Volume 2: Interactivity, Platforms, Application*. ACM.

Montesinos, L., Salinas-Navarro, D. E., and Santos-Diaz, A. (2023). Transdisciplinary experiential learning in biomedical engineering education for healthcare systems improvement. *BMC Medical Education*, 23(1):207.

Nuñez, T. R., Jakobowsky, C., Prynda, K., Bergmann, K., and Rosenthal-von der Pütten, A. M. (2023). Virtual agents aligning to their users. lexical alignment in human–agent-interaction and its psychological effects. *International Journal of Human-Computer Studies*, 178:103093.

Petersen, G. B., Mottelson, A., and Makransky, G. (2021). Pedagogical agents in educational vr: An in the wild study. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA. Association for Computing Machinery.

PlayCanvas (2024). https://playcanvas.com/, Accessed Jan. 25, 2025.

Ready Player Me (2024). https://https://readyplayer.me/it, Accessed Jan. 25, 2025.

Ryu, J. and Baylor, A. L. (2005). The psychometric structure of pedagogical agent persona. *Technology Instruction Cognition and Learning*, 2(4):291.

Schroeder, N. L., Adesope, O. O., and Gilbert, R. B. (2013). How effective are pedagogical agents for learning? a meta-analytic review. *Journal of Educational Computing Research*, 49(1):1–39.

Septiana, A. I., Mutijarsa, K., Putro, B. L., and Rosmansyah, Y. (2024). Emotion-related pedagogical agent: A systematic literature review. *IEEE Access*.

Sikström, P., Valentini, C., Sivunen, A., and Kärkkäinen, T. (2022). How pedagogical agents communicate with students: A two-phase systematic review. *Computers & Education*, 188:104564.

Sketchfab (2024). https://sketchfab.com/, Accessed Jan. 25, 2025.

Tao, Y., Zhang, G., Zhang, D., Wang, F., Zhou, Y., and Xu, T. (2022). Exploring persona characteristics in learning: A review study of pedagogical agents. *Procedia computer science*, 201:87–94.

Zhang, S., Jaldi, C. D., Schroeder, N. L., López, A. A., Gladstone, J. R., and Heidig, S. (2024). Pedagogical agent design for k-12 education: A systematic review. *Computers & Education*, page 105165.