ICCEPM 2024 https://dx.doi.org/10.6106/ICCEPM.2024.1220
The 10th International Conference on Construction Engineering and Project Management
Jul. 29-Aug.1, 2024, Sapporo

Integrating Conversational AI-Based Serious Games to Enhance Problem-Solving Skills of Construction Students

Aqsa Sabir[1]* & Rahat Hussain[2] & Syed Farhan Alam Zaidi[2] & Muhammad Sibtain Abbas[2] & Nasrullah Khan[2] & Doyeop Lee[2] & Chansik Park[2]*

[1]Department of Computer Science and Engineering, Chung Ang University, Seoul South Korea
Email address: aqsasabir786@gmail.com
[2]ConTI Lab, Department of Architectural Engineering, Chung-Ang University, Seoul, South Korea
Email address: rahat4hussain@gmail.com, farhanzaidi@cau.ac.kr, muhammadsibtain@cau.ac.kr, nasazzam@cau.ac.kr, doyeop@cau.ac.kr, cpark@cau.ac.kr
**Corresponding Author*

Abstract:
In the construction industry, professionals are required to have advanced problem-solving skills to adeptly handle the dynamic challenges inherent to project execution. These skills are crucial, as they enable professionals to effectively navigate the complexities and unpredictability of construction projects, ensuring timely and cost-effective completion. This paper explores an innovative approach to enhance the problem-solving skills of construction students through the integration of conversational AI-based serious games into their educational curriculum. The objective of this research was acquired by following three phases: hazard interaction, problem identification, and AI-guided text-based communication. This approach creates an engaging learning environment, simulating real-world construction challenges and problems, focusing on the excavation phase of a construction project as a case study for students to interact with and communicate with the Conversational AI agent through text-based prompts. In the future, the proposed study can be used to evaluate how AI agents can help enhance problem-solving skills by promoting emotional engagement among participants. This research sheds light on the potential of integrating conversational AI in education, providing valuable insights for educators designing construction management training programs by underscoring the importance of engagement in real-world problem-solving scenarios.

Keywords: Conversational AI, Construction, Safety Education, Virtual Reality, Problem-solving skills,

1. Introduction and Background:

The construction industry, known for its dynamic and often hazardous environments, requires robust problem-solving skills from its professionals [1]. This becomes especially critical when interacting with potential hazards and identifying problems that may arise on construction sites. Traditional methods, such as lectures and theoretical instruction, which offer foundational knowledge for developing problem-solving skills, have been found to be inadequate in preparing students for the real-world challenges of the construction industry [2]–[4]. Consequently, researchers have explored alternative strategies to enhance these skills, including gamification, case studies (detailed examination of a particular case within a real-world context), role-playing exercises, and simulation-based learning [5]–[7].

Among these approaches, gamification has emerged as a promising method to enhance problem-solving skills in construction students [8]. Through the incorporation of game elements, such as virtual environments, into educational frameworks, instructors can craft immersive learning experiences that simulate hazard identification and mitigation scenarios [9], [10]. A key component of gamification, serious games, has gained traction for its ability to blend entertainment with educational objectives, thereby fostering deeper learning and skill development [11], [12].

Serious games encompass a wide range of interactive media designed to convey educational content while maintaining an engaging, game-like format. Originating from the broader concept of gamification, serious games have evolved to address specific learning objectives across various domains, including healthcare, business, and education [13]–[15]. Within the realm of construction management education, serious games offer a compelling platform for students to identify problems associated with particular hazards and solutions to mitigate those hazards within a safe and controlled environment [16].

Furthermore, providing students with guidance within the gaming environment can lead to more effective learning outcomes [17], [18]. However, the gamification approach often lacks personalized and adaptive feedback, highlighting the need for communication-based guidance to deliver customized support and to augment the overall learning experience. For this purpose, Conversational AI is a promising solution which can be integrated into serious games to mark a significant advancement in the educational approach [19]. Conversational AI, also known as virtual agents, leverages natural language processing techniques to facilitate interactive communication between users and AI systems [20]. By integrating conversational AI into serious games, students can engage in simulated conversations to identify hazards and explore potential solutions, thereby sharpening their problem-solving skills.

This paper proposes an educational system that incorporates conversational AI-based serious games into the construction curriculum. This research aims to offer students a more engaging and effective way to develop the crucial skills needed for hazard interaction and problem identification in construction projects. Drawing upon insights from literature and educational theory, the proposed approach seeks to create an immersive learning environment wherein students interact with AI-guided prompts to recognize and address construction-related hazards. Through text-

based communication with the AI agent, students can engage in collaborative problem-solving exercises aimed at mitigating potential risks. In the manuscript, Section 2 examines the technical implications of the research, including system development, Smart Knowledge Training of Conversational AI NPC, and gaming framework as key subsections. Following this, Section 3 and 4 encompasses a thorough discussion and conclusion of the proposed research respectively.

2. Technical Implementation:

2.1.System Development

The development of serious games was motivated by the objective of incorporating conversational AI to enrich the training process for construction students. The content was meticulously crafted in accordance with the situated cognition learning theory, a widely recognized framework that underscores the acquisition of knowledge and skills through interactive engagement with conversational AI [21].

The mentioned theory was adopted to develop realistic construction scenarios fostering clear communication within specific contexts [22]. In response to the urgent safety concerns and high accident rates, the focus was directed towards designing scenarios related to excavation hazards. These scenarios were particularly aimed at tasks involving excavators, recognized as risky within the construction industry.

Hence, the proposed system offers students a platform within the virtual environment to effectively interact with hazards and identify problems within the environment. They can approach AI NPCs with the help of chatbots designed within the virtual system for assistance with their queries and engage in constructive conversations, thereby enhancing their problem-solving skills. **Figure 1** illustrates the architecture of a text-based conversational interface between students and an AI NPC. This architecture is designed such that when a student poses a query, it is transmitted directly to the AI platform for processing. This query, serving as user input, is then relayed to the underlying database for evaluation. Subsequently, the processed query is relayed back to the AI platform, now as an output tailored for the user. This output is subsequently displayed on the chatbot interface as a response from AI NPC in textual form, completing the interaction cycle.

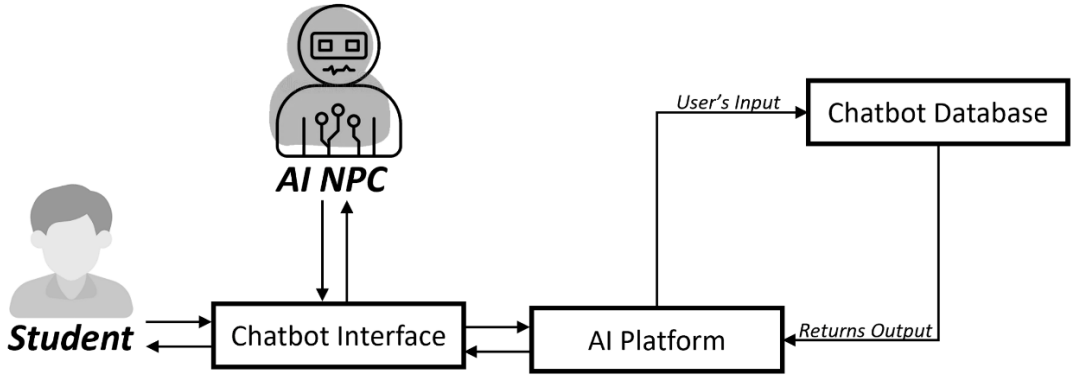

Figure 1: Chatbot Architecture

To develop the system, a pre-existing 3D virtual construction site from the Sketchfab Marketplace was employed for an immersive simulated construction environment to offer a realistic depiction of a construction site within the virtual domain. Furthermore, additional virtual 3D objects, including buildings, construction equipment, and items associated with excavation hazards, were either procured from the Unity Asset Store or generated using Blender 3.5 software. These components were seamlessly integrated within the Unity Game Engine (Version: 2021.3.16f1) to facilitate a cohesive and interactive construction training experience. Moreover, authentic construction machinery sounds and site noises were simulated to replicate the auditory ambiance of an actual construction site.

Continuing, the process of developing artificial intelligence non-playing characters (NPCs) within the virtual environment for training construction students relied on utilizing the Ready Player Me[1] (RPM) platform. The AI NPC was imported into the virtual environment with the help of RPM plugin. Following this, to facilitate the smart knowledge training of the AI NPC, the Convai[2] platform by NVIDIA was utilized. This platform assigns a distinctive identifier (ID) to each AI NPC created, facilitating their smooth integration into the gaming platform alongside the specific avatar designated for integration as shown in **Figure 2**.

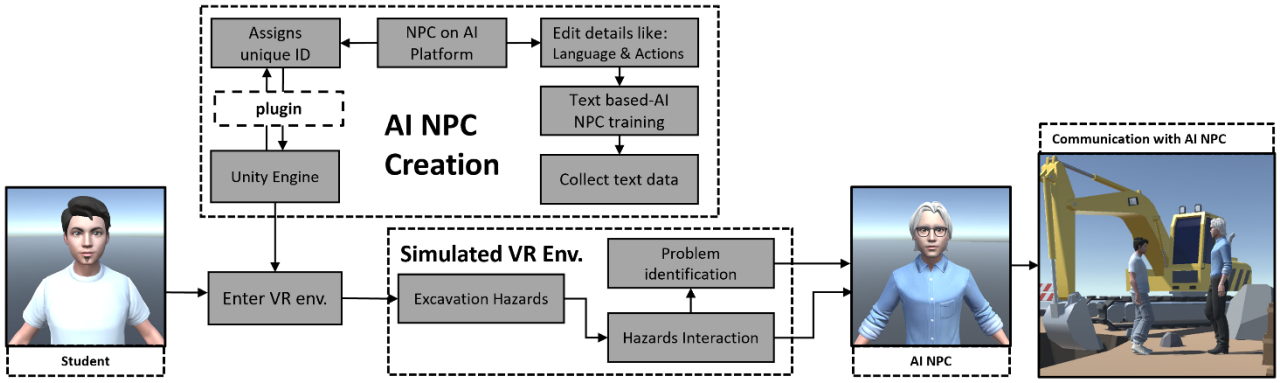

Figure 2: Architectural Framework for Hazard Recognition and Communication with AI NPC in Construction Education

2.2.Smart Knowledge Training of Conversational AI NPC

In this section, the process unfolds as: Users initiate a query, which is directly forwarded to the database on the Convai platform. This database cross-references the character history, a repository structured according to specified character requirements for AI NPCs. Additionally, to provide comprehensive responses, a knowledge bank exclusively comprising .text, .pdf, and .docs files, designated for the smart knowledge training of AI NPC, is utilized. Information from the knowledge bank is retrieved to augment the responses of the character, subsequently returned to

[1] https://readyplayer.me/
[2] https://convai.com/

the database for query evaluation. The database then analyzes the query of the user and furnishes a response tailored to the inquiry of the user (**Figure 3**).

The incorporation of conversational AI NPCs, facilitated by platforms such as Convai and Ready Player Me avatars, introduces an interactive dimension to the learning process. Through text-based interactions, students can ask for assistance, make inquiries, and receive guidance from AI NPCs, thereby enriching their problem-solving abilities in construction-related scenarios. This functionality heavily relies on smart knowledge training process for effective communication and response generation from Conversational AI.

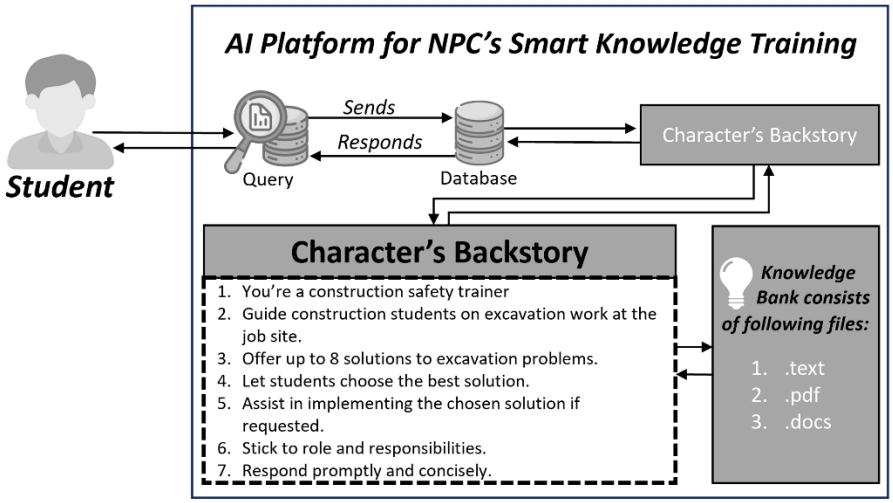

Figure 3: Framework Design for smart knowledge training of AI NPC

2.3. Gaming Framework:

To effectively address the three distinct phases - hazard interaction, problem identification, and AI-guided communication as elaborated in **Figure 2**- the proposed research necessitates that students enter in a virtual simulated environment. This environment is designed for active engagement and interaction with construction hazards. Specifically, students encounter activity scenarios involving excavation hazards, where risks such as fall from height are prominently featured. To mitigate these hazards, students can consult the AI NPC for potential solutions in the third phase of AI-guided communication. The AI NPC offers multiple options, fostering critical thinking and decision-making skills among students. They can assess the effectiveness, feasibility, and safety implications of each solution before making an informed choice.

Following the selection of a solution, students can seek guidance from the AI NPC on its implementation at the jobsite to mitigate potential damage by verifying the availability of necessary resources. If these resources are accessible, students can proceed to implement the chosen solution for hazard mitigation. Conversely, if the resources are not available – a scenario that falls under the problem identification phase – students are required to recheck the available solutions. This iterative process, along with the communication with the AI NPC, is comprehensively depicted in **Figures 4** and **5** respectively. This personalized approach aids

students in comprehending the rationale behind each solution and learning to apply it effectively in practical contexts. Moreover, the problem-solving skills honed within the proposed VR environment can directly be transferable to real-world construction settings. Students can acquire hands-on experience in hazard identification, risk assessment, and safety management, all of which are indispensable competencies in the construction industry.

Figure 4: Interaction between AI NPC and Construction Students Focusing on Identifying and Addressing Construction Hazards

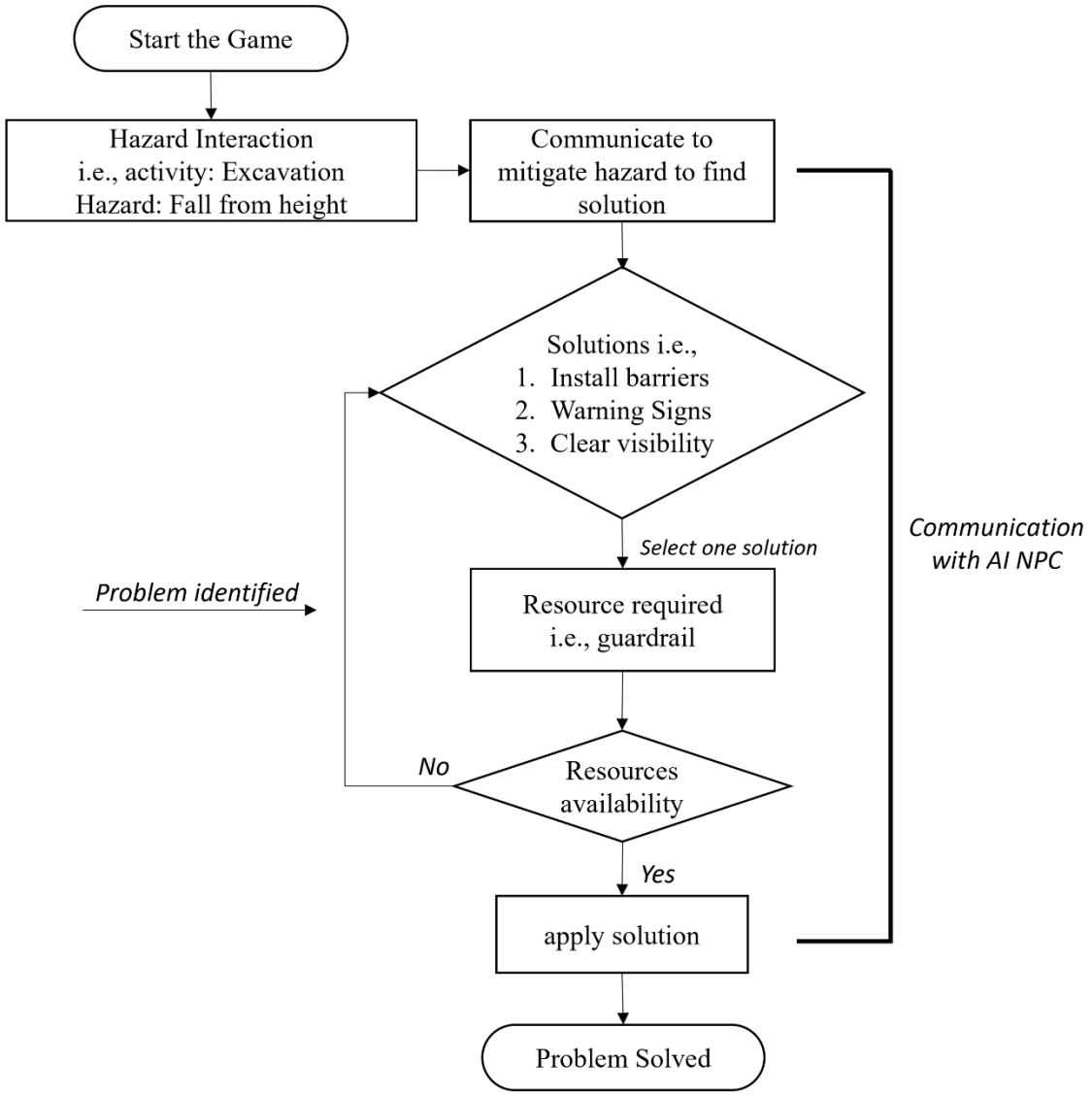

Figure 5: Flowchart of Hazard Interaction, Problem Identification, and Hazard Mitigation.

3. Discussion:

This proposed approach overcomes the lack of practical hazard interaction and problem-solving training in conventional construction education. Leveraging serious games grounded in situated cognition learning theory, it provides an immersive experience beyond traditional classroom methods, as evidenced by research showing the effectiveness of serious games in enhancing safety training [16]. The simulation of real construction sites in virtual environments through serious games is key to develop enhanced learning and problem-solving skills in construction students [23].

Incorporating conversational AI NPCs into these virtual gaming environments adds a layer of interactivity, essential for fostering skills such as problem-solving, communication, and critical thinking. These AI NPCs act as guides and facilitators within the game, improving communication

and decision-making capabilities of students. Interaction with AI characters exposes students to diverse problem scenarios, fostering an enriched understanding and response mechanism to typical construction site challenges. Moreover, serious games have shown significant potential in educational settings, influencing mood and engagement of learners [24]. By blending conversational AI with serious games, this method provides an engaging way for students to acquire essential skills, highlighting the importance of innovative educational tools in higher education.

4. Conclusion

This research has established a foundational step in the development of a conversational AI-based serious game for construction education. The developed system aims to promote active learning and the development of practical and problem-solving skills as well as emotional engagement which is essential for construction professionals. For the future, a comprehensive evaluation to assess the effectiveness of the system in real educational settings is needed, which will pave the way for the success of this research. This study is a testament to the potential of integrating advanced AI technologies into construction education and training, paving the way for future research and development in this field. As the construction industry progresses, the methods used to educate its future leaders must also advance, incorporating innovative, effective, and engaging educational experiences.

Acknowledgements:

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. NRF-2022R1A2B5B02002553). This research was conducted with the support of the "National R&D Project for Smart Construction Technology (No.RS-2020-KA156291)" funded by the Korea Agency for Infrastructure Technology Advancement under the Ministry of Land, Infrastructure and Transport, and managed by the Korea Expressway Corporation.

References:

[1] P. A. Cummins, T. Yamashita, R. J. Millar, and S. Sahoo, “Problem-Solving Skills of the U.S. Workforce and Preparedness for Job Automation,” *Adult Learn.*, vol. 30, no. 3, pp. 111–120, Aug. 2019, doi: 10.1177/1045159518818407/ASSET/IMAGES/LARGE/10.1177_1045159518818407-FIG3.JPEG.

[2] R. Hussain *et al.*, “Conceptual Framework for Safety Training for Migrant Construction Workers using Virtual Reality Techniques,” 2022, Accessed: Feb. 13, 2024. [Online]. Available: https://www.researchgate.net/publication/366004620

[3] J. Zhang, H. Xie, and H. Li, “Improvement of students problem-solving skills through project execution planning in civil engineering and construction management education,” *Eng. Constr. Archit. Manag.*, vol. 26, no. 7, pp. 1437–1454, Aug. 2019, doi: 10.1108/ECAM-08-2018-0321/FULL/PDF.

[4] A. • Canada, • Mexico, and O.-S. Tan, “Problem-Based Learning Innovation Using Problems to Power Learning in the 21st Century,” 2003, Accessed: Feb. 05, 2024.

[Online]. Available: http://www.cengagelearningasia.com

[5] C. Uzun and K. Uygun, “The Effect of Simulation-Based Experiential Learning Applications on Problem Solving Skills in Social Studies Education.,” *Int. J. Contemp. Educ. Res.*, vol. 9, no. 1, pp. 28–38, Mar. 2022, doi: 10.33200/ijcer.913068.

[6] O. Ö. Özener, “Context-based learning for BIM: simulative role-playing games for strategic business implementations,” *Smart Sustain. Built Environ.*, vol. ahead-of-print, no. ahead-of-print, 2023, doi: 10.1108/SASBE-08-2022-0184/FULL/PDF.

[7] P. C. Lin, H. T. Hou, and K. E. Chang, “The development of a collaborative problem solving environment that integrates a scaffolding mind tool and simulation-based learning: an analysis of learners’ performance and their cognitive process in discussion,” *Interact. Learn. Environ.*, vol. 30, no. 7, pp. 1273–1290, 2022, doi: 10.1080/10494820.2020.1719163.

[8] L. M. Putz, F. Hofbauer, and H. Treiblmaier, “Can gamification help to improve education? Findings from a longitudinal study,” *Comput. Human Behav.*, vol. 110, p. 106392, Sep. 2020, doi: 10.1016/J.CHB.2020.106392.

[9] Y. Choi, Hyeongho ; Chae, Jeonghyeun ; Kang, “Job Training and Safety Education for Modular Construction using Virtual Reality,” *Korean J. Constr. Eng. Manag.*, no. 2005–6095, p. pp.63-72, 20233, doi: https://dx.doi.org/10.6106/KJCEM.2023.24.5.063.

[10] H. Imran, “An Empirical Investigation of the Different Levels of Gamification in an Introductory Programming Course,” *J. Educ. Comput. Res.*, vol. 61, no. 4, pp. 847–874, Jul. 2023, doi: 10.1177/07356331221144074/ASSET/IMAGES/LARGE/10.1177_07356331221144074-FIG10.JPEG.

[11] D. Serious *et al.*, “Serious Games and Soft Skills in Higher Education: A Case Study of the Design of Compete!,” *Electron. 2023, Vol. 12, Page 1432*, vol. 12, no. 6, p. 1432, Mar. 2023, doi: 10.3390/ELECTRONICS12061432.

[12] J. Son, S.-W. Shin, and J.-S. Yi, “Application of Serious Games for Effective Construction Safety Training,” *Korean J. Constr. Eng. Manag.*, vol. 15, no. 1, pp. 20–27, Jan. 2014, doi: 10.6106/KJCEM.2014.15.1.020.

[13] T. Beranič and M. Heričko, “The Impact of Serious Games in Economic and Business Education: A Case of ERP Business Simulation,” *Sustain. 2022, Vol. 14, Page 683*, vol. 14, no. 2, p. 683, Jan. 2022, doi: 10.3390/SU14020683.

[14] J. Hutson, B. Fulcher, and J. Weber, “Gamification in Education: A Study of Design-Based Learning in Operationalizing a Game Studio for Serious Games,” *J. Intell. Learn. Syst. Appl.*, vol. 14, Nov. 2022, Accessed: Feb. 05, 2024. [Online]. Available: https://digitalcommons.lindenwood.edu/faculty-research-papers/440

[15] “Journal of Medical Internet Research - Conceptual Ambiguity Surrounding Gamification and Serious Games in Health Care: Literature Review and Development of Game-Based Intervention Reporting Guidelines (GAMING).” https://www.jmir.org/2021/9/e30390/ (accessed Feb. 05, 2024).

[16] Z. U. Din and G. E. Gibson, “Serious games for learning prevention through design concepts: An experimental study,” *Saf. Sci.*, vol. 115, pp. 176–187, Jun. 2019, doi:

10.1016/J.SSCI.2019.02.005.

[17] M. Taub, R. Sawyer, A. Smith, J. Rowe, R. Azevedo, and J. Lester, “The agency effect: The impact of student agency on learning, emotions, and problem-solving behaviors in a game-based learning environment,” *Comput. Educ.*, vol. 147, p. 103781, Apr. 2020, doi: 10.1016/J.COMPEDU.2019.103781.

[18] R. Hussain *et al.*, “Conversational AI-based VR system to improve construction safety training of migrant workers,” *Autom. Constr.*, vol. 160, p. 105315, Apr. 2024, doi: 10.1016/J.AUTCON.2024.105315.

[19] N. Rane, S. Choudhary, and J. Rane, “Integrating Building Information Modelling (BIM) With ChatGPT, Bard, and Similar Generative Artificial Intelligence in the Architecture, Engineering, and Construction Industry: Applications, a Novel Framework, Challenges, and Future Scope,” *SSRN Electron. J.*, Nov. 2023, doi: 10.2139/SSRN.4645601.

[20] M. Allouch, A. Azaria, and R. Azoulay, “Conversational Agents: Goals, Technologies, Vision and Challenges,” *Sensors 2021, Vol. 21, Page 8448*, vol. 21, no. 24, p. 8448, Dec. 2021, doi: 10.3390/S21248448.

[21] S. Fox, “Situated learning theory versus traditional cognitive learning theory: Why management education should not ignore management learning,” *Syst. Pract.*, vol. 10, no. 6, pp. 727–747, 1997, doi: 10.1007/BF02557922/METRICS.

[22] “Instructional Design in Serious Game for Learning based on Inquiry and Situated Learning Theory.” https://www.researchgate.net/publication/269166010_Instructional_Design_in_Serious_Game_for_Learning_based_on_Inquiry_and_Situated_Learning_Theory (accessed Feb. 03, 2024).

[23] D. Fonseca *et al.*, “Mixed Assessment of Virtual Serious Games Applied in Architectural and Urban Design Education,” *Sensors 2021, Vol. 21, Page 3102*, vol. 21, no. 9, p. 3102, Apr. 2021, doi: 10.3390/S21093102.

[24] Y. Zhonggen, “A Meta-Analysis of Use of Serious Games in Education over a Decade,” *Int. J. Comput. Games Technol.*, vol. 2019, 2019, doi: 10.1155/2019/4797032.