

Board 197: A Gamified Approach for Active Exploration to Discover Systematic Solutions for Fundamental Engineering Problems

Dr. Mohammad Ilbeigi, Stevens Institute of Technology

Mohammad Ilbeigi is an Assistant Professor in the Department of Civil, Environmental, and Ocean Engineering (CEOE) at Stevens Institute of Technology.

Dr. Diana Bairaktarova, Virginia Tech

Dr. Diana Bairaktarova is an Assistant Professor in the Department of Engineering Education at Virginia Tech. Through real-world engineering applications, Dr. Bairaktarova's experiential learning research spans from engineering to psychology to learning

Romina Ehsani

Understanding of Engineering Core Concepts Contextualized in Domain-Specific Settings Through Active Exploration

Abstract

This study explores students' ability to discover systematic solutions for fundamental engineering problems contextualized in domain-specific settings through active exploration in a digital game environment. To address this objective, through a research project funded by the NSF Division of Engineering Education and Centers (EEC), we designed and developed a scenario-based interactive digital game, called Zebel, to guide students in solving fundamental problems in construction scheduling. The proposed gamified pedagogical approach was designed based on the Constructivism learning theory. We also designed a series of pre- and post-assessment instruments for empirical data collection to assess the effectiveness of the proposed approach. The proposed gamified method was implemented in a graduate-level construction planning and scheduling course. The outcomes indicated that students with no prior knowledge of construction scheduling methods were able to discover systematic solutions for fundamental scheduling problems through their experience with the proposed gamified learning method.

Introduction

Previous studies indicated that active and collaborative instruction, coupled with effective means to encourage student engagement, invariably leads to better student learning outcomes irrespective of academic discipline [1-2]. Despite these findings, the existing construction engineering programs, for the most part, rarely offer a systematic approach to allow students to develop a deep understanding of the engineering core concepts and discover systematic solutions for fundamental problems. Without properly understanding these core concepts, contextualized in domain-specific settings, students are not able to develop a holistic view that will help them to recognize the big picture and think outside the box to come up with creative solutions for arising problems [3]. An essential element to address this need that is missing in traditional content-centered and didactic teaching methods is an opportunity for active exploration and empirical learning. The long history of empirical learning in the field of construction engineering shows the significant potential of cognitive development through direct experience and reflection on what works in particular situations [4]. Of course, the complex nature of the construction industry in the twenty-first century cannot afford an education through trial and error in the real environment. However, recent advances in computer science can help educators develop virtual environments and gamification platforms that allow students to explore various scenarios and learn from their experiences. More specifically, digital gamified solutions can be used to create an interactive virtual environment where students can learn through guided active exploration.

Gamification in construction engineering education

Gamification or serious games is the application of game-design elements and game principles in non-game contexts [5]. If designed properly, serious games can provide an interactive

environment where learners can engage with technical contexts, explore different scenarios, acquire new knowledge, and connect that knowledge to their existing mental models [6]. The state-of-the-art application of computer simulation and gamification tools in construction engineering can be categorized into three groups. The first group concentrates on a general introduction to the field by presenting its main products (e.g., bridges, dams, and skyscrapers) to K-12 students. The goal is to increase students' awareness about their built environment and motivate them to consider engineering careers in the construction industry. Examples include the ASCEville [7], developed by the American Society of Civil Engineers (ASCE). The second group of computer tools aims to simulate construction activities and processes for construction engineering students, thereby helping them to develop a better and more realistic comprehension of construction projects. Examples include Sawhney et al. [8]. The third group of computer tools, including the one developed by Ayer et al. [9], uses 360-degree immersive digital environments to interact in a virtual-reality construction site. Still, these efforts neither offer a systematic approach to educating students about engineering core concepts nor do they provide an interactive environment where students can explore solutions for real-world construction problems.

Objective

The primary objective of this study is to investigate the effectiveness of a pedagogical strategy based on guided active exploration in a digital game environment for construction engineering education. More specifically, this study aims to assess whether guided active explorations in a digital game environment improve students' ability to discover systematic strategies to solve fundamental problems in construction engineering and how students perceive this strategy as a formal learning tool.

Research design

To address the objective of this study, we designed and developed an online game called Zebel. The game provides an interactive digital environment in which users try to solve fundamental problems in the domain of construction planning and scheduling presented in realistic scenarios through guided active explorations. Figure 1 shows a snapshot of the game. The scenario-based problems facilitate sense-making and engage students in understanding, analyzing, and solving open-ended problems in that field. During the active explorations to solve these fundamental problems, the users are exposed to fundamental engineering problems and try to discover systematic solutions to solve them. The game and the proposed gamified pedagogy are designed based on the Constructivism learning theory and a framework that consists of six essential elements: (1) modeling; (2) reflection; (3) strategy formation; (4) scaffolded exploration; (5) debriefing; and (6) articulation [10].

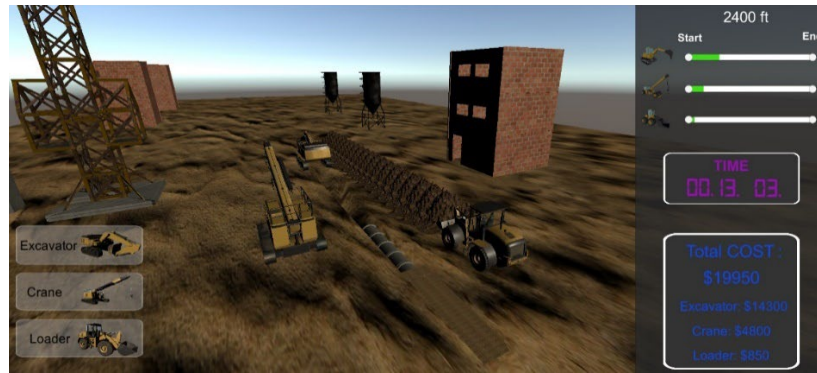


Figure 1: A snapshot of the Zebel game

Results

The proposed gamified pedagogical method was implemented in a graduate-level course titled CM-529: Construction Planning and Scheduling in the Department of Civil, Environmental, and Ocean Engineering (CEOE) at Stevens Institute of Technology in Fall 2022. Consent forms were administered on the first day of class. All 40 students agreed to participate in this study. The results of the prior knowledge survey indicated that 10 students had some level of familiarity with the fundamentals of the Critical Path Method (CPM), the most prevalent scheduling system in construction projects. Their game data was excluded from the analysis process in this study. The outcomes indicated that 27 out of the 30 students with no prior knowledge of CPM worked on the assignment and submitted it before the deadline. The average number of trials to accomplish the game was 4.51, with a minimum of 1 and a maximum of 17 tries. The recorded log files indicate that students tend to schedule everything as soon as possible and gradually learn that they have to delay some of them to manage their resources. The log files show that the guiding mechanisms, including error messages, were able to effectively direct students to update their strategies and solve the problems. More specifically, 21 students received error messages related to the logical order of the activities in the project, but all of them were able to fix the issue in the following rounds. Twenty-seven percent of the error messages were related to limited resource issues and reminded students that their current schedule needed pieces of equipment more than what was available. The data collected through the debriefing and articulation mechanisms indicated all students were able to solve the problems, and more than 55% of them were able to clearly explain the fundamental concepts and discover systematic solutions for the presented problems.

Conclusion

In this study, a novel gamified pedagogical method was designed, and its effectiveness on students' ability to discover systematic solutions for fundamental construction scheduling problems was empirically assessed. The outcomes indicated that the proposed methodology was able to effectively guide students to solve fundamental engineering problems and discover systematic solutions for them.

References

- [1] Kuh, G. D., Kinzie, J., Schuh, J. H., & Whitt, E. J. (2011). Student success in college: Creating conditions that matter. John Wiley & Sons.
- [2] Weimer, M. (2002). Learner-centered teaching: Five key changes to practice. John Wiley & Sons.
- [3] National Research Council. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. National Academies Press.
- [4] Boothby, T. (2018). Empirical Structural Design for Architects, Engineers and Builders. Institute of Civil Engineers (ICE) Publishing. London. United Kingdom.
- [5] Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in education: A systematic mapping study. *Journal of Educational Technology & Society*, 18(3).
- [6] Deshpande, A. A., & Huang, S. H. (2011). Simulation games in engineering education: A state-of-the-art review. *Computer applications in engineering education*, 19(3), 399-410.
- [7] ASCEville, <https://www.asceville.org/>
- [8] Sawhney, A., Marble, J., Mund, A., & Vamadevan, A. (2000). Internet based interactive construction management learning system. In *Construction Congress VI: Building Together for a Better Tomorrow in an Increasingly Complex World* (pp. 280-288).
- [9] Ayer, S. K., Messner, J. I., & Anumba, C. J. (2016). Augmented reality gaming in sustainable design education. *Journal of Architectural Engineering*, 22(1), 04015012.
- [10] Obikwelu, C., & Read, J. C. (2012). The serious game constructivist framework for children's learning. *Procedia Computer Science*, 15, 32-37.