2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #39349

Lessons Learned from a Game-Based Learning Intervention in Civil Engineering

Dr. Casper Harteveld, Northeastern University

Dr. Casper Harteveld is an Associate Professor of Game Design at Northeastern University, has affiliated appointments in Computer Science, Electrical & Computer Engineering, Mechanical & Industrial Engineering, and with the School of Law, and works closely with faculty in Marine Science and Public Policy. His research focuses on using games to study and improve decision-making, and through these efforts both to advance our knowledge and to engage a broad cross-section of people globally about societal issues. He applies games especially in areas where it is challenging to study and educate in natural environments and collects detailed and expansive behavioral data in a controlled manner.

Working across disciplines, Dr. Harteveld has designed and evaluated games on flooding, urban heat islands, debris collection, and pro se litigants. He is a strong proponent of integrating research and education and a significant portion of his work is devoted to translating research outcomes to the classroom or informal settings, in order to make sure that the next generation is ready to deal with the societal challenges of the 21st Century.

Victoria Bennett, Rensselaer Polytechnic Institute
Dr. Yevgeniya V. Zastavker, Olin College of Engineering

Yevgeniya V. Zastavker, Ph.D., is an Associate Professor of Physics at Franklin W. Olin College of Engineering and a recent Director of the Research Institute for Experiential Learning Science at Northeastern University. She earned her B.S. degree in Phy

Dr. Usama El Shamy, P.E., Southern Methodist University

Dr. Usama El Shamy is an assistant professor in the Civil and Environmental Engineering Department at Southern Methodist University. He received his Ph.D. in Civil Engineering from Rensselaer Polytechnic Institute in 2004. He is the Principal Investigator

Dr. Binod Tiwari, University of Michigan

Dr. Tiwari is a professor of civil and environmental engineering at California State University Fullerton. His research interest includes geotechnical earthquake engineering, soil behavior, slopes dams and embankment, natural hazard mitigation, and engine

Dr. Anirban De, P.E., Manhattan College
Xenia Wirth
Kejun Wen, Jackson State University

Dr. Kejun Wen is an Assistant Professor at the Department of Civil an Environmental Engineering in Jackson State University

Dr. David A Saftner, Northern Arizona University

David Saftner is an Associate Professor at the University of Minnesota Duluth. He received a BS in Civil Engineering from the United States Military Academy and MS and Ph.D. in Civil Engineering from the University of Michigan.

Prof. Beena Ajmera, Iowa State University
Scott Brandenberg, University of California, Los Angeles

Scott is a Professor in the Department of Civil and Environmental Engineering and the Associate Dean for Diversity and Inclusion for the Samueli Engineering School at UCLA.

Dr. Alison Rose Kennicutt, York College of Pennsylvania

Alison is an Assistant Professor of Civil Engineering at York College of Pennsylvania. She received her B.S. in Civil Engineering and her M. Eng. and Ph.D. in Environmental Engineering from Rensselaer Polytechnic Institute in Troy, NY. Her research interests are in drinking water treatment of emerging contaminants and the production of disinfection byproducts. At York College, Alison loves to use hands-on exploration, both in the field and the lab, to trigger curiosity and get students excited about engineering!

Surya Sarat Chandra Congress
Anthony Tessari
Mehdi Omidvar
Ashly Cabas

Lessons Learned from a Game-Based Learning Intervention in Civil Engineering

Abstract

The aim of our project is to create a scalable and sustainable educational model of mixed reality gaming in civil engineering education that provides practical experiences, develops engineering judgment competency, and engages a diverse student audience. Specifically, we have been building a game-based learning module focused on experiencing the field testing technique cone-penetration testing (CPT). As part of the module, students start a virtual internship at a fictional engineering company. After being briefed through a lecture on CPT, they enter a 3D (game) environment where they conduct CPTs. Students analyze CPT data extracted from the environment and submit a report. To assess student experience of this module, we collected pre/post surveys, game data (including in-game assessments), and student/faculty interviews. In this paper, we report the findings of implementing this CPT module in the initial three years of the project (2016-2019) at five institutions. Overall, we find that students are engaged, especially women and students from historically marginalized communities, increase their knowledge and confidence in the subject matter, and find the module valuable to gain much-needed (field) experience. More recently, we find that the game-based learning intervention seems resilient and, in fact, a solid solution to the disturbances caused by the pandemic, with many students providing positive remarks about being able to experience hands-on learning, which is key to quality engineering education and difficult to achieve through online education. Opportunities for improvement exist regarding access to technology, as well as the instructional design. While we demonstrate the scalability of this approach across multiple institutions and classrooms, open questions remain on how to transform institutions to embed game-based learning not as an intervention but as a key part of the curriculum.

Introduction

In recent decades, government and industrial leaders, policy makers, academic and funding agencies have been calling for drastic shifts in engineering education [1-3]. Since engineering practice relies on one's ability to understand potential problems and design appropriate solutions, one of the more frequently cited needs for engineering education is that students engage in *practical training* and *gain authentic hands-on experience* [4-6]. For example, Kosa et al. [7] highlight that traditional "theory-only" methods do not provide novice engineers with an understanding of real problems that engineers face in the field; Ma et al. [8] argue that "real" hands-on experience is ideal for educating the future engineering workforce; and Tan et al. [9] suggest that to fully realize the practical constraints and realities of the work, students are "inserted into a situation." Moreover, literature demonstrates that authentic learning experiences result in deeper and more engaged learning in groups under-represented in STEM [e.g., 6, 10, 11].

The difficulty in providing students with authentic engineering experiences is that real case studies are difficult, costly, and often impossible (natural disasters are prime examples of cases that are impossible to reproduce). According to ABET, engineering students should, among other things, “learn from failure,” “identify health, safety, and environmental issues and deal with them responsibly,” and “use the human senses to gather information and to make sound *engineering judgments* in formulating conclusions about real-world problems” [5]. The revised ABET student outcomes further call out the need for *engineering judgment* as follows: (i) “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts”; and (ii) “an ability to develop and conduct experimentation, analyze and interpret data, and use engineering judgment to draw appropriate conclusions” [12]. These objectives cannot be accomplished without having students make decisions in an authentic environment, where engineering judgment competency is developed and assessed within a “real” engineering context.

Additionally, despite the calls for change and consistent research findings demonstrating its weaknesses, classical engineering education prevalent throughout academe, continues to rely on traditionalist educational models, in which the teacher “transmits” information and the student acts as passive recipient [e.g., 13]. In comparison, much of the recent literature has focused on the effectiveness of non-traditional educational practices in improving students’ performance, engagement with and motivation in engineering [e.g., 14-17]. Specifically, student-centered active learning environments that are based on constructivist epistemological traditions have been positively correlated with deeper learning, greater student *engagement*, and shifts in students’ motivational outcomes from the extrinsic to the intrinsic end of the motivational continuum as defined by SDT [e.g., 18-21]. Of importance is that such environments seem to benefit all students, particularly those underrepresented in STEM, in terms of their motivational outcomes [22], as well as performance and engagement in learning [23]. By integrating (mixed reality) gaming into traditional engineering curricula, this work is attempting to provide a diverse student audience with opportunities for gaining practical experience in virtual realistic world settings while fostering development of engineering judgment competency and shifting their motivational attitudes towards the internalized end of the motivational spectrum [24-26].

Mixed Reality Gaming Opportunity for Engineering Education

Gaming has gained widespread attention as a powerful educational tool [26]. Among other benefits, games provide immediate formative and summative feedback [27] in a virtual space that creates authentic context [28, 29], can serve as a tool for “capturing and maintaining” learning motivation [30-33], and can position users as experts, giving them the ability to enact practices that they typically do not have access to in the real world [18]. In their report, the Federation of American Scientists [34] concluded that games may be especially effective in developing such higher-order skills as decision-making because “in games, players are making decisions continually, in contrast to low levels of decision-making in traditional learning” (p. 43). A recent engineering education literature review by our advisor Cheryl Bodnar and co-authors [26] found that in 191 papers published since 2000, a game was used for an undergraduate engineering course. Of these, only 62 papers report on the learning outcomes, suggesting a dearth in empirical evidence; however, the analysis indicates that 87% of these papers report positive, 13% neutral, and 0% negative student learning outcomes. The authors therefore conclude that there “is a general trend that both student learning and attitudes are improved by game-based activities.”

Particularly relevant to this work is the approach to learning that combines real and virtual elements, i.e., *mixed reality* learning. Such environments have the potential to support positive motivational and learning outcomes afforded by the game-based learning approach while also providing students the benefit of authentic hands-on training [8]. This kind of blended approach can act as a bridge between the theoretical “know-what” and the practical “know-how” [35, 13] by giving students the opportunity to learn theoretical knowledge in the context of a practical application. In fact, a study [36] of more than 100,000 students found that 70% of U.S. respondents report learning most in blended educational environments. Mixed reality thus shows great promise, but that promise requires careful design and implementation: In a comprehensive review of the literature, Akçayıra and Akçayır [37] report that mixed reality education initiatives improve learning performance, but that the usability remains a strong bottleneck. Wu et al. [38] identify that mixed reality solutions need to be clear about the envisioned roles of teachers and students, educational tasks, real and virtual locations, and emphasize that careful design along these lines will enable mixed reality-based solutions to help students learn.

The Game!

GeoExplorer is an educational game developed for undergraduate classroom settings to aid in the instruction of geotechnical engineering (i.e., a subdiscipline of civil engineering). The vision guiding this game development is to provide experience for undergraduate civil engineering students with various field testing techniques for which students traditionally have little to no hands-on exposure [39]. The game is positioned within an activity framed as a virtual internship in which the player (student) is working for the geotechnical engineering firm, Terra Inc. The game experience utilizes a website (representing the firm) and a local virtual environment (VE) and requires players to calculate results retrieved from the VE and then upload these to the website, which is why we refer to it as a mixed reality game: it mixes virtual elements with typical classroom exercises (e.g., calculation with Excel). However, most of the gameplay is happening in the VE (Figure 1). The current version of the game focuses on Cone Penetration Testing (CPT). Through the activity of identifying soil types across different locations via CPT, students have an opportunity to explore and extract CPT data. The elements that comprise the CPT module include: pre-survey embedded on the website; CPT lecture (a pre-recorded version is available to instructors to utilize in a flipped classroom style); playing in the virtual environment (four field sites available) with embedded knowledge, confidence, and reflection prompts; post-survey embedded on the website; and suggested laboratory report assignment (sample prompt for report and model report available to instructors). In this section, we provide a detailed “gameflow” description that depicts what happens in the game.

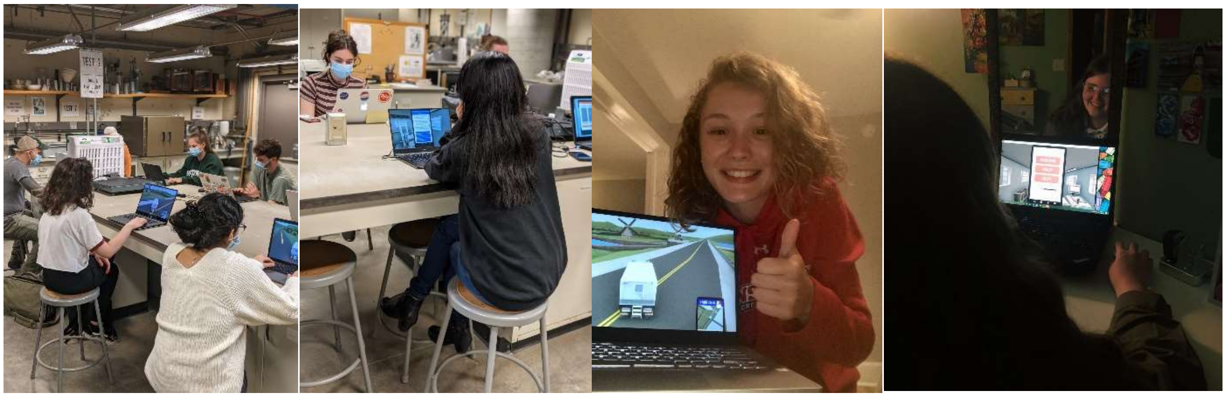


Figure 1. Students playing *GeoExplorer* in the geotechnical engineering lab and at home.

Gameplay. After registering on the website and starting up the VE, the gameplay involves four key stages: Driving (players need to drive to the correct location of where the CPT needs to happen), Preparation (players need to take a number of steps that are essential before conducting a CPT (e.g., clean the cone, level the truck)), CPT (the actual CPT occurs, which essentially involves reading graphs on a computer screen), and Analysis (after retrieving the CPT results, players need to determine the soil type). The VE consists of four unique CPT locations, namely Farmland (Scenario 1), Land Reclamation (Scenario 2), Industrial Area (Scenario 3), and Levee (Scenario 4). Each of these location scenarios presents its own unique soil stratigraphy, offering the player multiple opportunities to learn about subsurface soil behavior types. The player must drive around the VE from location to location, perform CPTs, and assess the soil types for each location. They are assisted by Maya Jones, their in-game project manager, who messages them at key moments of the game (Figure 2). If the CPT is performed correctly, then the player can determine the soil type for a particular location at a requested depth and submit their assessment to Maya. The player is also required to submit their CPT data and accompanying report to the website so that it can be accessed and checked by their real-world course instructor.

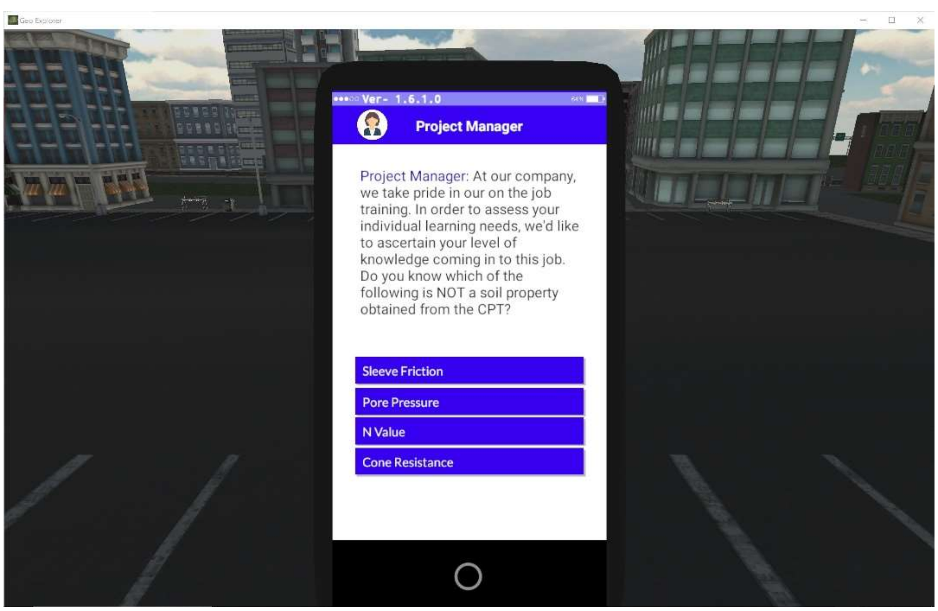


Figure 2. Messaging from project manager via in-game phone.

In the VE, the player is given a CPT truck and a mobile phone. Once the player logs into the VE they are greeted by a text message from their project manager Maya, who quizzes the player on their knowledge and confidence about field testing. Following this, the player needs to drive their truck to one of the four locations to perform a CPT. The Farmland location (Scenario 1) is automatically selected for the player, though they can choose to select a different one. Once at the designated location, the player can switch their game view to the inside of the truck, which is equipped with various gear required for a CPT. Here the player first needs to prepare the truck for the test, such as inserting the right cone into the tower, which pushes the cone into the soil. Once the required preparatory steps are done, the player can access the truck computer and initiate the CPT data collection. The CPT data collection screen shows multiple graphs and a few buttons that control the CPT (Figure 3). These controls allow the player to accurately control the rate and depth at which the cone is pushed into the soil. After getting the cone to an appropriate depth, the player can end the data collection process, prompting the VE to print out the CPT data as a CSV file and png of the graphs to the player's actual computer. This data is later used to calculate the Soil Behavior Type (SBT) index at a requested depth.

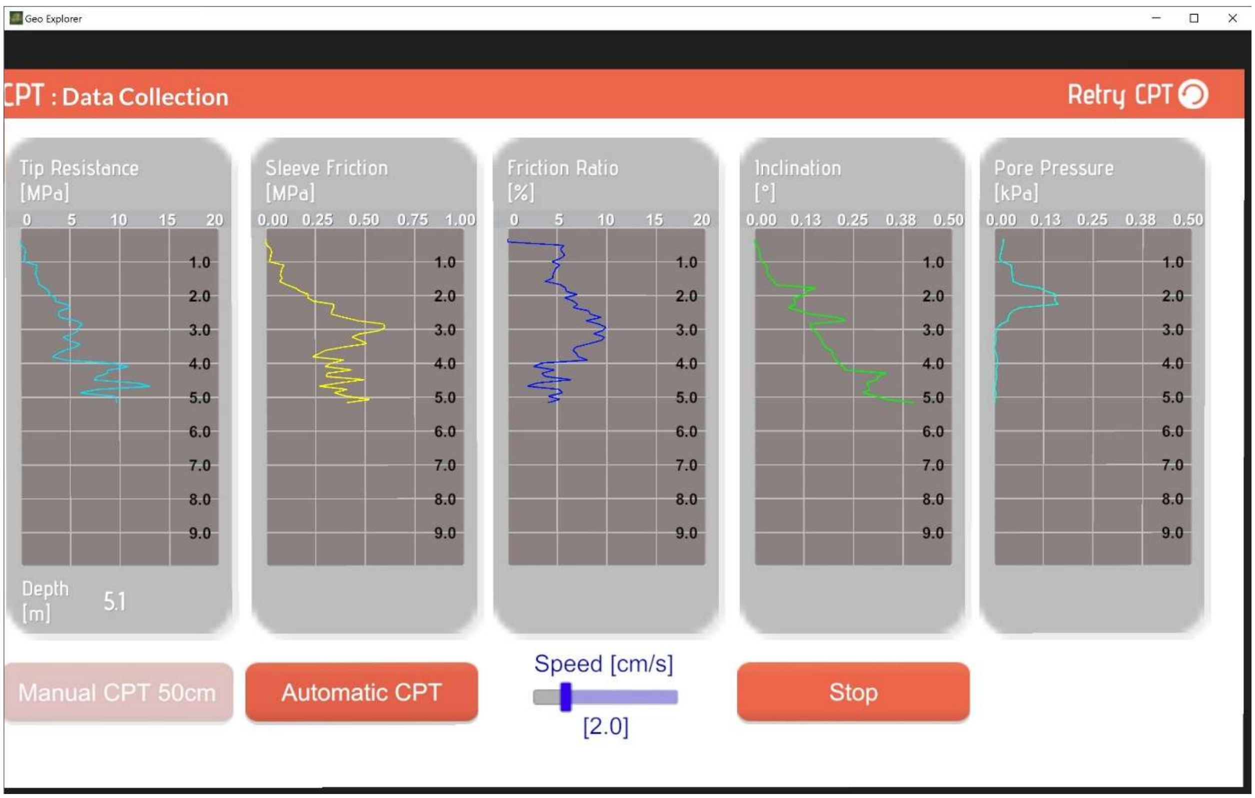


Figure 3. CPT data collection on the in-game computer.

Then the player moves on to the CPT pre-analysis screen, which they use to calculate and check the SBT value. At this point, Maya will message the player and ask them to calculate the SBT value at a certain depth. An interactive SBT chart assists the player with this calculation, though they can also use a calculator or spreadsheet software with the data in the CSV file. The player can try to submit their calculated SBT value to check if it is correct or not. If the value is correct, then they receive a text message from Maya, who asks them to identify the soil type at the location based on their analysis. There is only one correct answer for each location. Once the player replies to Maya, the current scenario ends, and they are presented with a *Score & Feedback* screen, which includes a breakdown of the four stages and brief comments explaining the scores. The provided feedback is minimal but can suggest what to improve on (e.g., "The CPT speed is too fast. The data correlations may not be valid."). This screen is intended to serve as a moment of reflection.

The scoring system of *GeoExplorer* is split into four different stages, not counting the bonus driving score, which does not impact the total score. The scoring is based on the four distinct stages involved in the CPT process: preparation, CPT data collection, CPT pre-analysis, and soil type analysis. The scores and assigned values have been developed together with domain experts and are described herein.

Preparation: the player can gain up to 20 points for this stage by completing all 7 actions prior to starting the truck computer. Out of the 7 actions available, 3 actions are required to move to the next one. The required actions are: cleaning the cone (2 points), putting the cone in the tower (4 points), and fixing the cable if it is broken (3 points; a broken cable happens randomly, if it is not broken then the 3 points are automatically awarded). The other actions are: putting on work clothes (2 points), using the shovel to dig a hole (3 points), raising the cone tower (3 points), and leveling the truck (4 points).

CPT data collection: the maximum available points for this stage is 30. The speed of the CPT and final depth are what dictate performance. It is possible to gain just 1 point if done incorrectly, or even having to restart the CPT if the player manages to break the cone by digging too deep at very high speeds. If the player observes the various graphs indicating the cone's tip resistance, friction ratio, and inclination, they can control for optimal speed and depth of the cone required at the location. The following actions are included in this stage:

- The use of manual drilling at the appropriate time and range. Zero points are awarded if manual drilling is not used at the start of CPT. Otherwise, 5 points are awarded for using manual drilling in the perfect depth range and 2 points if not within this range.
- The use of optimal automatic drilling speed. If the speed is optimal, then 5 points are awarded; slower or higher than optimal is 3 points; and extremely high is 1 point.
- Stopping the drilling at the optimal soil depth. This optimal soil depth is decided based on the depth the SBT index needs to be calculated for the location. If the final depth of the cone is within the optimal range, then 20 points are awarded. If it is slightly higher or lower, then 18 points are awarded for being in the sub-optimal range. They are awarded 10, 5, and 0 points if they stop at progressively incorrect ranges.

CPT pre-analysis: the player can gain 20 points if they submit the correct SBT value right away. With each incorrect SBT submission, they lose 2 points. The only action in this stage is to find the correct SBT value using the interactive SBT graph. They separately enter this value into an input box to check if they are correct. If incorrect, they lose 2 points each time they enter an incorrect value.

Soil type analysis: this final stage only allows one attempt to give the correct answer. The project manager Maya asks the player what soil type exists at the requested depth, and gives nine options to choose from (e.g., silt mixtures, organic soils, clay, sand). Based on the SBT value, the player can figure out the soil type in the location. If they provide the correct soil type, then they get 30 points, otherwise, they are awarded zero points.

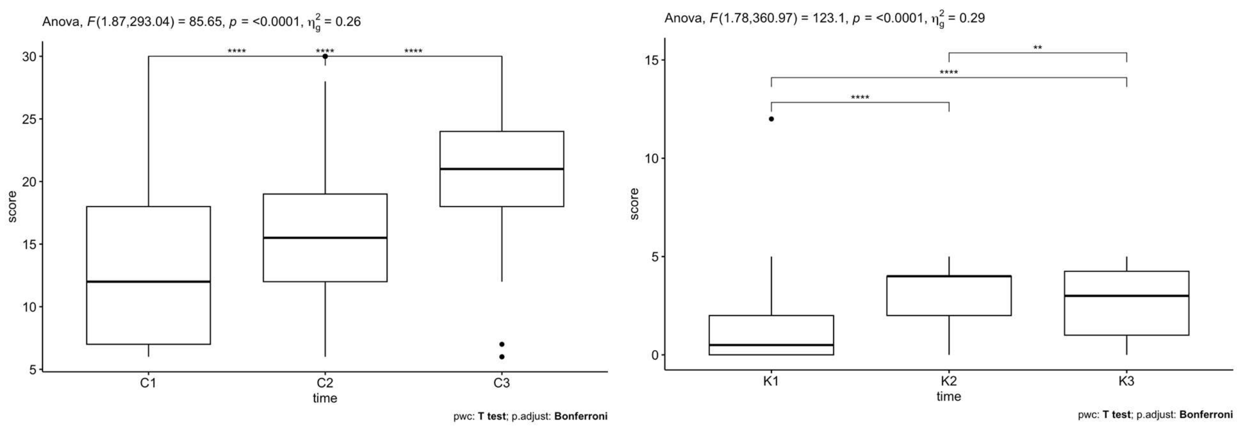
The total number of points related to the above-mentioned four stages concerns 100 points. For driving, players can gain up to an additional 10 bonus points, which means players can get a maximum score of 110. The feedback at the end of the scenarios consists of both numerical and textual feedback. For example, if players did not identify the correct soil type they will see at the end "Incorrect soil type analysis". Such textual feedback was included in order to provide immediate feedback to the player, along with the numerical scores.

Results

In the initial three years of this project, we gradually implemented three different versions of *GeoExplorer* at four different universities, reaching a total of approximately 500 students in the period of 2016 to 2019. During this period, we iterated the game by addressing software bugs and feedback we received from students and instructors, as well as by fine-tuning the curriculum, when possible, and the supporting materials for an effective implementation. We report here the results of two semesters where we implemented a mature version of the game and scaled the implementation to reach many students ($n = 263$). Due to the nature of the data collection, which involved the voluntary completion of pre/post-surveys and the retrieval of game data, some data from participants is missing.

Overall, students indicated that they were very satisfied with the experience ($M = 3.47$, $SD = 0.71$; scale 1 to 4) with 58% of students being extremely satisfied and only 2% expressing dissatisfaction. Students found *GeoExplorer* to be effective in teaching the CPT content ($M = 15.83$, $SD = 3.01$; scale 4 to 20, $\alpha = .93$); to help increase perception of geotechnical engineering relevance ($M = 22.52$, $SD = 4.80$; scale 6 to 30, $\alpha = .95$); and, for a significant group (32% scored 16 or higher), to increase interest in pursuing a career in civil engineering (e.g., a graduate degree in geotechnical engineering, employment with a geotechnical engineering firm, etc.; $M = 13.21$, $SD = 3.96$; scale 4 to 20, $\alpha = .95$).

Furthermore, we considered assessments on student confidence and knowledge prior to the lecture, at the start of playing the game, and after playing two scenarios (Figure 4). Student confidence was statistically significantly different at the different time points, $F(1.87, 293.04) = 85.65$, $p < .0001$, $\eta^2_G = 0.26$. Post-hoc analyses with a Bonferroni adjustment revealed that all the pairwise differences between time points were statistically significantly different ($p <= 0.05$). Thus, students gained in confidence at each time measured, as a result from listening to the lecture and then playing the game. For student knowledge, we also find a statistically significantly difference at the different time points, $F(1.78, 360.97) = 123.1$, $p < .0001$, $\eta^2_G = 0.29$, and statistically significant differences ($p <= 0.05$) between the time points. However, here we see that knowledge increased after the lecture but was not further increased after playing. In fact, while scores after playing were still significantly higher than before the lecture they were lower compared to after the lecture. These results warrant further investigation, particularly to better understand why a further increase in knowledge is not occurring after students experience the game. This requires a further examination of the game data. It may be that the knowledge assessment used is more specifically tuned to content delivered through a lecture, and a recency effect might explain why scores are higher after the lecture compared to after playing. Regardless, students expressed learning from the experience and the results demonstrate that both the lecture and the game play a role in improving student knowledge and confidence, providing evidence that they should be combined (i.e., mixed reality).



(a) Confidence measures over time (b) Knowledge measures over time

Figure 4. Boxplots of confidence (C) and knowledge (K) before the lecture (1), at the start of the game (2), and after playing two scenarios (3). Pairwise comparison (pwc) is calculated with t-tests and a Bonferroni adjustment.

Qualitative data and anecdotes further help confirm our game-based learning approach. The students expressed that the website inclusion and narrative context of a virtual internship made the experience feel "more real": students' open-ended responses indicate their appreciation of gaining practical experience ("It gave me an experience on [sic] the field while in a classroom" and "the game shows what happens in real life") and ability to analyze "real" data. Some called the experience "perfect just the way it is" and others wanted more of it: "Make there be more issues, more things we'd experience on the field." Of importance to the project, we heard that employers hiring *GeoExplorer*-trained students for intern positions were impressed with students' CPT experience and were curious about how this experience was gained. To examine attainment of our goal of engaging a diverse audience, we reviewed the outcomes across gender and race/ethnicity. We did not find any differences [40], suggesting that our approach is suitable for everyone and does not create equity issues.

Conclusion

In this paper, we highlight our efforts around implementing the *GeoExplorer* game. We find that students are engaged, increase their knowledge and confidence in the subject matter, and find the module valuable to gain much-needed (field) experience.

Though in the early stages of the data analysis, we believe that tools such as this are incredibly important in times of online learning and decreasing retention rates. Anecdotally, students are citing lack of engagement as a reason for leaving higher education. We believe that a mixed reality gaming educational model may help mitigate the impact of COVID-19-like crises. Student and instructor reflections captured quantitatively and qualitatively through mixed modes revealed confirmation of this belief. *GeoExplorer* is a tool that is still under development to include more practical experience and opportunities for students to develop engineering judgment. As instructors are asked by ABET to document more complicated student outcomes (e.g., engineering judgment and inclusive environment[s]) and by Gen Z students to create an engaging and applied learning environment, we will continue to unpack the lessons learned through this project and share more broadly with the civil engineering educational community.

References

1. National Academy of Engineering. "**Educating the Engineer of 2020: Adapting Engineering Education to the New Century**" (2005):
2. National Academy of Engineering Committee on Public Understanding of Engineering. "**Changing the Conversation: Messages for Improving Public Understanding of Engineering**" (2008):
3. National Academy of Engineering, U. "**The Engineer of 2020: Visions of Engineering in the New Century**" (2004):
4. Council, N. R. and others. "**Engineering in K-12 Education: Understanding the Status and Improving the Prospects**" (2009):
5. Feisel, L. D. and Rosa, A. J. "**The Role of the Laboratory in Undergraduate Engineering Education**" *Journal of Engineering Education* 94, no. 1 (2005): 121–130.
6. Webster-Wright, A. "**Reframing Professional Development through Understanding Authentic Professional Learning**" *Review of educational research* 79, no. 2 (2009): 702–739.
7. Kosa, M., Yilmaz, M., O'Connor, R. V., and Clarke, P. M. "**Software Engineering Education and Games: A Systematic Literature Review**" *Journal of Universal Computer Science* 22, no. 12 (2016): 1558–1574.
8. Ma, J., Tucker, C. S., Okudan Kremer, G. E., and Jackson, K. L. "**Exposure to Digital and Hands-on Delivery Modes in Engineering Design Education and Their Impact on Task Completion Efficiency**" *Journal of Integrated Design and Process Science* 21, no. 2 (2017): 61–78. doi:10.3233/jid-2016-0021
9. Tan, K. H., Tse, K. Y., and Chung, L. P. "**A Plug and Play Pathway Approach for Operations Management Games Development**" *Computers & Education* 55, no. 1 (2010): 109–117. doi:10.1016/j.compedu.2009.12.008, Available at http://dx.doi.org/10.1016/j.compedu.2009.12.008
10. Treviño-Guzmán, N. and Pomales-García, C. "**How Can a Serious Game Impact Student Motivation and Learning?**" *Proceedings of the 2014 Industrial and Systems Engineering Research C* (2014):
11. Creswell, J. W. and Clark, V. L. P. "**Designing and Conducting Mixed Methods Research**" (2007):
12. McCullough, C. L. "**A Plan to Assess All the New ABET Outcomes Using Only Three Courses**" (2018):
13. Muller, J. "**The Future of Knowledge and Skills in Science and Technology Higher Education**" *Higher Education* 70, (2015): 409–416. doi:10.1007/s10734-014-9842-x, Available at http://dx.doi.org/10.1007/s10734-014-9842-x
14. Nie, Y. and Lau, S. "**Differential Relations of Constructivist and Didactic Instruction to Students' Cognition, Motivation, and Achievement**" *Learning and Instruction* 20, no. 5 (2010): 411–423.

15. Paris, S. G. and Paris, A. H. "**Classroom Applications of Research on Self-Regulated Learning**" *Educational psychologist* 36, no. 2 (2001): 89–101.
16. Stefanou, C., Stolk, J. D., Prince, M., Chen, J. C., and Lord, S. M. "**Self-Regulation and Autonomy in Problem-and Project-Based Learning Environments**" *Active Learning in Higher Education* 14, no. 2 (2013): 109–122.
17. Stolk, J. D. and Martello, R. "**Can Disciplinary Integration Promote Students' Lifelong Learning Attitudes and Skills in Project-Based Engineering Courses**" *International Journal of Engineering Education* 31, no. 1 (2015): 434–449.
18. Dillon, A., Stolk, J., Zastavker, Y. V., and Gross, M. and. "**Motivation Is a Two-Way Street: Pedagogies Employing Discussion in Addition to Lecture Display More Positive Student Motivational Response**" (2016):
19. Herman, G. L., Goldberg, D. E., Trenshaw, K. F., Somerville, M., and Stolk, J. "**The Intrinsic Motivation Course Design Method**" *International Journal of Engineering Education* 33, no. 2 (2013):
20. Pintrich, P. R. "**The Role of Motivation in Promoting and Sustaining Self-Regulated Learning**" *International journal of educational research* 31, no. 6 (1999): 459–470.
21. Ryan, R. M. and Deci, E. L. "**Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions**" *Contemporary educational psychology* 25, no. 1 (2000): 54–67.
22. Stolk, J., Zastavker, Y. V., and Gross, M. "**Gender, Motivation, and Pedagogy in the STEM Classroom: A Quantitative Characterization**" (2018):
23. Zastavker, Y. V., Ong, M., and Page, L. "**Women in Engineering: Exploring the Effects of Project-Based Learning in a First-Year Undergraduate Engineering Program**" *Frontiers in Education Conference, 36th Annual* (2006): 1–6.
24. Deci, E. L., Vallerand, R. J., Pelletier, L. G., and Ryan, R. M. "**Motivation and Education: The Self-Determination Perspective**" *Educational psychologist* 26, no. 3–4 (1991): 325–346.
25. Ryan, R. M. and Deci, E. L. "**Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being.**" *American psychologist* 55, no. 1 (2000): 68.
26. Bodnar, C. A., Anastasio, D., Enszer, J. A., and Burkey, D. D. "**Engineers at Play: Games as Teaching Tools for Undergraduate Engineering Students**" *J. Eng. Educ.* (2016):
27. Gresalfi, M. S. and Barnes, J. L. "**Designing Feedback in an Immersive Videogame: Supporting Student Mathematical Engagement**" *Educ. Technol. Res. Dev.* (2015): 1–22.
28. Gee, J. "**What Video Games Have To Teach Us about Learning and Literacy**" (2003):
29. Squire, K. D. "**Video Games and Learning: Teaching and Participatory Culture in the Digital Age**" (2011):
30. Orvis, K. A., Horn, D. B., and Belanich, J. "**The Roles of Task Difficulty and Prior Videogame Experience on Performance and Motivation in Instructional Videogames**" *Computers in Human Behavior* 24, no. 5 (2008): 2415–2433. doi:10.1016/j.chb.2008.02.016
31. Papastergiou, M. "**Digital Game-Based Learning in High School Computer Science Education: Impact on Educational Effectiveness and Student Motivation**" *Computers & Education* 52, (2009): 1–12. doi:10.1016/j.compedu.2008.06.004, Available at http://dx.doi.org/10.1016/j.compedu.2008.06.004

32. Wiggins, B. E. "**An Overview and Study on the Use of Games, Simulations, and Gamification in Higher Education**" *International Journal of Game-Based Learning* 6, no. 1 (2016): 18–29. doi:10.4018/IJGBL.2016010102
33. Yang, Y.-T. C. "**Building Virtual Cities, Inspiring Intelligent Citizens: Digital Games for Developing Students' Problem Solving and Learning Motivation**" *Computers & Education* 59, no. 2 (2012): 365–377. doi:10.1016/j.compedu.2012.01.012, Available at http://linkinghub.elsevier.com/retrieve/pii/S0360131512000139
34. Federation of American Scientists. "**Summit on Educational Games: Harnessing the Power of Video Games for Learning**" (2006):
35. Vahed, A., Mckenna, S., and Singh, S. "**Linking the 'know-That' and 'Know-How' Knowledge through Games: A Quest to Evolve the Future for Science and Engineering Education**" *Higher Education* 71, no. 6 (2016): 781–790. doi:10.1007/s10734-015-9956-9
36. Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., and Ludgate, H. "**NMC Horizon Report: 2013 Higher Education Edition (2013)**" *Austin, Texas, USA* 44.
37. Akçayir, M. and Akçayir, K. "**Advantages and Challenges Associated with Augmented Reality for Education: A Systematic Review of the Literature**" *Education Research Review* 20, (2017): 1–11. doi:10.1016/j.edurev.2016.11.002
38. Wu, H.-K., Lee, S. W.-Y., Chang, H.-Y., and Liang, J.-C. "**Current Status, Opportunities and Challenges of Augmented Reality in Education**" *Computers & Education* 62, (2013): 41–49. doi:10.1016/j.compedu.2012.10.024, Available at http://dx.doi.org/10.1016/j.compedu.2012.10.024
39. Bennett, V., Abdoun, T., Harteveld, C., McMartin, F., and El Shamy, U., "**Classroom implementation of game-based module for geotechnical engineering education**," *Proceedings of ASEE Annual Conference and Exposition*, (2017): 1-11.
40. Harteveld, C., Javvaji, N., Machado, T., Zastavker, Y. V., Bennett, V., and Abdoun, T. "**Gaming4All: Reflecting on Diversity, Equity, and Inclusion for Game-Based Engineering Education**," *2020 IEEE Frontiers in Education Conference (FIE)*, Uppsala, Sweden, (2020): 1-9, doi: 10.1109/FIE44824.2020.9274176.