GeoExplorer and Gender Identity: The Impact of Gender in a Game-Based Learning Environment

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***Abstract*—This Work-in-Progress research paper focuses on the game-based learning environment of *GeoExplorer,* a digital learning tool that simulates Cone Penetration Testing (CPT) – a field test that civil engineers conduct to understand soil properties. This paper aims to investigate the gendered patterns of student interaction with *GeoExplorer,* if any, and the associated gendered patterns of content comprehension and self-efficacy related to one's ability to pursue CPT in the field, if any. As such, we ask: (1) How, if at all, does gender affect a student's belief in their ability to apply skills gained through engagement with *GeoExplorer* in real world environments? and (2) How, if at all, do prior gaming experience and gender impact the *GeoExplorer* play experience? Four open-ended semi-structured interviews regarding students' experience with gameplay, gender identity, and learning were analyzed. Preliminary analyses used narrative and grounded theory approaches. Our early findings indicate a lack of student insight on the role of their gender identity on their gameplay experience and the presence of a gendered impact of gameplay on student learning and self-efficacy in carrying out CPT in the field.**

Keywords—game-based learning, civil engineering, self-efficacy, gender

I. Introduction and Literature Review

This Work-in-Progress research paper investigates the effectiveness of digital game-based learning – a "type of learning environment" that takes place virtually and incorporates "game content and game play" to engage students and improve their disciplinary content knowledge [1]. Game-based learning has been shown to improve learning outcomes and students' engagement in the learning process as well as provide a source of motivation [2][3][4]. Research to date has demonstrated that digital game-based learning is an effective tool for improving student STEM content comprehension. For example, Wang et al.'s (2022) meta-study determined that digital games may serve as "a promising pedagogical method" to effectively improve learning gains in terms of content retention and long-term learning for both K-12 and higher education student groups in a variety of "different STEM subjects" [3]. A study by Chen and colleagues (2020) on the effectiveness of game-based learning in science learning at the K-12 level demonstrated improvements in both students' conceptual understanding and overall learning experiences across all achievement levels [4]. Chau et al.'s study (2013) demonstrated that, for college students, constructivist learning in virtual environments facilitates higher levels of control leading to higher levels of interest and engagement [5]. Pertinent to our work, Wood et al.'s recent study (2022) on the effectiveness of learning in virtual spaces established that such spaces support nursing students' confidence in their ability to perform in real-world situations (e.g., resuscitation) [6].

Given the demonstrated overall efficacy of digital game-based learning, how does this pedagogical practice serve to improve diversity in engineering and provide equitable learning opportunities for all students, including students of all genders? Women are underrepresented in engineering education: according to NSF (2018), women make up 22.2% of all the earned bachelor's degrees in engineering [7]. Recent studies on the efficacy of game-based learning for a diverse population of students, however, seem to diverge in their findings. Some research shows that the improvements in learning achievement are consistent across men and women populations [8], and that both "females" and "males" benefit equally from game-based learning [9]. In a 2014 study that "examined how self-regulated learning (SRL) and gender influences performance in an educational game for 8th-grade students," Nietfield et al. found that "girls performed at similar levels as boys in the game despite incoming disadvantages for perceived skill and prior gaming experience." However, this same study also identified gendered differences in usage of cognitive tools, which disappeared when prior experiences were taken into account [10]. Based on a multi-year participant ethnography in game culture, other scholars found that women "were significantly more vulnerable to stereotype threat in gaming, and that it had measurable effects on their gaming self-concept (or self-confidence) and gaming identification" which made them "perform more poorly" [11].

Nietfield's more recent study (2020) on the effects of game-based learning environments on knowledge and skill transfer outside of game environments further considered gendered learning gains along cognitive and non-cognitive axes [12]. Specifically, in this latter work, Nietfield leveraged his 2014 findings that self-efficacy – a term coined by Albert Bandura in the 1970's to indicate a person's set of beliefs regarding confidence in their ability to perform a certain task [13][14] – is predictive of performance in game-based learning environments [10]. Together with the findings of Sung and Hwang (2013) and Meluso et al. (2012), Nietfield's work (2020) indicated that self-efficacy improves as the result of engaging with game-based learning [15][16], but that game-based learning experience designers have yet to more fully engage with game designs that create more equitable opportunities for men and women students

[12]. These studies furthered the findings about the gendered nature of engineering students' efficacy beliefs (e.g., [17][18]).

To contribute to a larger conversation about the effect of game-based learning on students' learning outcomes, including their efficacy beliefs, the current study investigates the impact of *GeoExplorer* on four students – two identifying as men and two identifying as women. *GeoExplorer* is a digital game-based learning environment that "allows students to explore aspects of geotechnical engineering that are too expensive to include in a traditional laboratory or require rare natural events to take place" [19][20]. This paper focuses on *GeoExplorer*'s Cone Penetration Testing (CPT) activity, in which students explore different soil types at various sites as part of a mock internship [21]. We ask the following inductively emergent research questions: (1) How, if at all, does gender affect a student's belief in their ability to apply skills gained through engagement with *GeoExplorer* in real world environments? and (2) How, if at all, do prior gaming experience and gender impact the *GeoExplorer* play experience?

Our goal is to extend the existing limited body of knowledge about gendered nature of students' learning outcomes in game-based learning environments. We expect that our emergent findings may support the design and implementation of more equitable game-based learning spaces for all students and expand research related to this pedagogical innovation.

II. Methods

As a part of a larger mixed-methods study about game-based learning, this exploratory qualitative investigation focuses on 4 interviews with 2 self-identified men (Elijah and Loid) and 2 self-identified women (Anya and Jessica) from three U.S. based institutions (two large public universities and one smaller, private college). Originally intended to be performed in-person, these interviews were ultimately conducted virtually due to the COVID-19 pandemic. Each student engaged with *GeoExplorer* in either an in-person or virtual classroom setting.

Open-ended semi-structured interview protocol was used to invite conversation about gameplay, student learning, and gender identity among other topics. The 4 out of 14 interviews reported in this study were the only ones in which students accepted the invitation to engage in a conversation about the ways in which their gender identity impacted their experience with *GeoExplorer*. (The analyses of other interviews, in which the same invitation was declined, and their comparison to the 4 interviews described here is the focus of an ongoing investigation that is outside of the scope of the current study.) Each interview lasted between 63 and 87 minutes. The interviews were transcribed and pseudonymized prior to analysis.

Our analytical approaches consisted of aspects of narrative analysis and grounded theory. Three scholars first read the transcripts for emergent ideas, accompanied by writing of narrative and comparative memos to help hone emergent ideas and to later substantiate themes emergent from grounded theory analyses. Early phases of grounded theory approaches – *in vivo*/open coding, followed by the beginnings of axial coding using ATLAS.ti – were then used. Through the ongoing use of memos, we engaged in the constant comparative method and iterative refinement, as well as integration of codes and categories to develop emergent themes reported on in this study [22][23]. The initial *in vivo*/open coding was conducted by each scholar individually and then discussed and an inter-coder reliability of 96% was established. The next three interviews were coded by all three scholars as a team. This process allowed for establishing data saturation, given analytical robustness and existence of other data sources. Specifically, our analyses included "prolonged engagement [with study participants, including instructors], … and thick, rich description; inter-rater reliability; peer review [and] debriefing [between PIs and student researchers]; clarifying researcher bias [through multiple iterative positionality statement memoing]; member checking; … and [preliminary] triangulation [using other data sources, including observations and instructor interviews]" [24].

III. Results and Discussion

In what follows, we describe the following three themes emergent from our analyses: (1) the schism between gender identity and gameplay experience; (2) gameplay and gendered efficacy beliefs related to one's perceived ability to implement CPT in the field; and (3) prior gaming experience and its gendered impact on students' gameplay.

A. Gender Identity and Gameplay Experience

When exploring the intersection between student gender identity and their gameplay experience, both men explicitly detached the two. For example, Elijah said that gender had nothing to do with the experience of the game and shared that his multiple identities are "independent of [his] ability to use the simulation." When Loid was asked about how his identity as a man affects his interaction with the game, he shared,

> *Well, I'm going to be honest, I don't think it really did. Because I just went about each of my tasks, and I performed my job. And I think, truthfully, at the end of the day, . . . it's not really a matter of somebody's gender, or identity, or really any of it, it's really just a matter of, 'Can you perform the tasks that you're assigned to do?' And so I went about doing it, I don't think it had any relevance to that. I don't think I noticed anything.*
>
> - Loid Murmurs, Birch Land State University

Loid believed that a person's ability to complete the game is independent of their identities or previous experiences they may have had. His statements that it's "not really a matter of somebody's gender" and that it is "just a matter of ... perform[ing] the tasks that you're assigned to do" are consistent with existing literature on STEM undergraduates' gender awareness, i.e., his positionality as a man allows for a certain blindness to the differences in experiences of different students under the social and societal structures that are at play even in the virtual environment provided (e.g., [25]).

On the other hand, when asked about how gender identity affected their gameplay, both women engaged with the question and they did so in two different ways. One woman, Anya, rather than responding to this prompt, chose to shift the conversation to her non-gaming identity compared to other students. Anya stated that gameplay was something she "wasn't used to" and that "other classmates that played a lot more video games" could understand "settings better than [she] could." When asked if there was "anything else about [her] multiple identities and how they may have interplayed with [her] engagement [with] the game," Anya responded,

> *Not that I can think of. Like you said, it's a very, very hard question to wrap around. . . Yeah, I don't really know.*
>
> - Anya Ross, Birch Land State University

Jessica did engage with the question about her gender identity more explicitly. She noted that one aspect of the gameplay – a lack of any visible features of the player's avatar – had a positive impact on her experience. She described a previous internship where, "as a fairly short young woman," she felt intimidated by her male coworkers who were "big tall dude[s]." Throughout her internship, she "saw . . . two women the entire summer," which she felt was "very weird." Jessica appreciated that, within *GeoExplorer*, the player never sees their avatar. This gameplay element made it a "very equalizing" experience for her,

> *any elements of intimidation or otherness are eliminated because you're just. . . you don't even have a body. Like, you put on a suit, shirt, but you never see yourself.*
>
> - Jessica Seagull, U of Cleotown Stonegrant

Jessica described this experience as "good" because neither her gender nor physique had an impact. Jessica also suggested how *GeoExplorer* might further support gender inclusivity – she stressed that if any features showing a person are to be included in the gameplay, the designers should "be aware of what type of people [they]'re showing and make sure that there's ...a variety."

Whether this game design creates a more equitable learning environment, as Jessica suggests, or enables gender to be invisible to the students with male privilege, as is evidenced by Elijah and Loid's comments, or serves both roles, remains a question for future investigation.

B. Gameplay and Gendered Efficacy Beliefs

Although this study did not set out to measure students' self-efficacy, the original interview protocol included several questions related to students' confidence related to their civil engineering education – whether STEM-centered or not – and their perceived role in the world as global citizens. While interviewing, however, students ventured to discuss their confidence as it relates to their ability to carry out CPT in the field post-engagement with *GeoExplorer,* i.e., efficacy beliefs and knowledge as well as skills transfer. Consistent with the grounded theory approach, when Bandura's social cognitive theory was used as an additional data source in our analyses, the open code related to one's belief to perform CPT in the field was later renamed to self-efficacy.

As a demonstration for how the study participants engaged with the confidence questions, the two men described themselves as confident in their ability to tackle world challenges and engage with challenging tasks. For example, Elijah believed "music's something you can teach yourself and get good at." He also described his fondness for tackling "challenging problems," such as those found on the mathematics Putnam Exam. Loid considered himself "qualified" to help address global water impurity challenges and spoke highly of his ability to learn quickly by following others' examples. When wondering about their confidence in performing CPT in the field after engaging with *GeoExplorer*, i.e., an emergent construct related to self-efficacy, Loid shared he could be "reasonably confident" as long as he had "a little more practice," and Elijah felt "85% confident" in his ability to complete the testing.

When addressing similar questions, women shared more complex narratives about both their confidence and ensuing efficacy beliefs related to their ability to transfer knowledge and skills into the field after engaging with *GeoExplorer*. For example, Anya started by sharing that she had stepped outside of her "comfort zone" by "leaving [her] smaller community" to attend college and described a willingness to try *GeoExplorer* despite her minimal gaming experience. Anya portrayed the challenges she faced and the way those shaped her ability to "be [her]self" and "thrive." When envisioning how she might perform CPT post- *GeoExplorer* activity, Anya reported that she would feel "pretty confident," but only if she were to complete the testing under the guidance of a "specialist," and not on her own. Jessica described herself as "a fairly outgoing person" who did not struggle with "speaking up" in class while attending a large school where she was "surrounded by a lot of students who have accomplished really great things." However, she also shared,

> *[while] activity gave me some confidence in my ability to analyze results for [CPT], I just don't think that . . . was enough for me to feel confident to do it myself.*
>
> - Jessica Seagull, U of Cleotown Stonegrant

Although both women described themselves as confident in other spaces, their descriptions of CPT-related efficacy beliefs were qualitatively different. The schism between Anya and Jessica's overall confidence and their self-efficacy in conducting CPT in the field may be related to a fundamental difference in the experience that *GeoExplorer*, or possibly game-based learning in general, provide women as opposed to men. Our findings further support Nietfield et al., (2014, 2020) in their calls for more scholarship to understand gendered self-efficacy, as well as knowledge and skills transfer related to game-based learning environments [10][12].

C. Prior Gaming and Gendered Gameplay Experience

Our emergent definition of "prior gaming experience" is that of any experience playing video games before *GeoExplorer* that is substantial enough for the participant to identify as a "gamer." Consistent with current literature that prior gaming experience is a gendered phenomenon, both men in our study spoke in detail about themselves as "gamers," whereas Anya reported having no prior experience. Jessica did not explicitly share her prior gaming experience. In this context, we further identify the impact of this gendered prior gaming experience on students' *GeoExplorer* gameplay.

When considering *GeoExplorer*'s content understanding, Elijah, a self-described "gamer," shared that he would consider his engagement with *GeoExplorer* as "effective learning" and "helpful." His reflection focused on specific actions taken in the game,

> *...it's one thing to hear about what's done in class and say as an engineer you're gonna go out to the site and ... drill into the ground with this bit... And then to get to do it. . . I guess you ...learn about maybe the preparation that goes into it, and I think there was a part in the game where . . . you . . . prep it, you put the bit on, and make your [CPT truck] level. . . And you attach a cone or something, some wires. . . But, maybe you learn some prep that goes into it. Like I said before, I think the most learning came from seeing the graph produced and then I think it just showed me . . . what each [soil] region was and what it meant.*
>
> - Elijah Santana, Richground College

When asked to reflect on the impact of prior gaming experience on his experience with *GeoExplorer*, Elijah discussed that having a background in video games allowed him to "maybe do *GeoExplorer* quicker 'cause [he] had an idea of what [he] could already do."

Loid, who had "played video games for a long time," felt that *GeoExplorer* was the kind of thing he "grew up doing." His retention of the material post-engagement with *GeoExplorer* was evident in his ability to provide minute details about the game. He commented that he had "obviously retained it for months at this point." Loid appreciated *GeoExplorer*'s "simulation" environment and felt that "with a little bit of practice and a little bit of application, [he] could . . . learn this long term, rather than learning it long enough to take tests and then forget about it."

In comparison, Anya said of the *GeoExplorer* experience,

> *I would have to say that . . . with my identities of not having a lot of experience [with] video games . . . it was not something that I was ordinar[ily using] for the classes, so it was kind of exciting and a little nerve wracking as it was something I wasn't used to, where[as] other classmates, who played a lot more video games, could navigate and knew what buttons could help with different video game settings, better than I did. So [this] was a little out of my comfort zone.*
>
> - Anya Ross, Birch Land State University

Having "not played very many video games growing up" compared to her classmates, *GeoExplorer* was a novel experience for Anya. Perhaps relatedly, Anya's main reflections on the game centered on the *GeoExplorer*'s cohesiveness rather than the in-game actions or the specific content learned. She described a wish for more "overview" and feeling like "pieces of the story were missing" in terms of the gameplay flow and the instructions about the CPT process and resulting graph interpretation. When asked about gameplay pacing, Anya detailed that she "might have [wanted to] slow it down" and would have wanted to try "getting a better understanding before jumping into the game, which definitely would have helped with the experience." Still, despite feeling "confused" and "frustrated" at times, Anya had a positive *GeoExplorer* experience, reporting that being able to "do something" with the content presented in class allowed her to "understand and retain the information better," an outcome consistent with current literature (e.g., [26]).

Consistent with literature on prior gaming experience, the two men in our study did not report facing the same frustrations, feeling rushed or missing relevant pieces of knowledge or skills, as did a woman participant. Further research is necessary to understand the ways in which gendered prior gaming experience affects college students' engagement with game-based learning environments and how game-based learning design must account for these differences.

IV. Conclusion

Game-based learning opportunities such as *GeoExplorer* are on the rise as a learning tool at all educational levels. This paper contributes to our knowledge of game-based learning environments and the gendered ways in which these environments are experienced by engineering undergraduates engaging with *GeoExplorer*.

Our preliminary findings indicate a paucity of student insight about the role of gender identity in their engagement with *GeoExplorer,* a finding consistent with literature on student blindness about the role of gender identity in their STEM education experiences. As well, consistent with current literature, our findings indicate gendered efficacy beliefs in students' ability to perform tasks or transfer knowledge and skills learned during game-based learning engagement. Our work further contributes to a growing literature – and research questions therein – related to game-based learning environment design, particularly as it pertains to gendered nature of interactions with gaming world (e.g., prior gaming experience) and the gendered in-game experience reported on in this study.

Given the inductive nature of our analyses, our results are not meant to be generalizable. Rather, consistently with grounded theory approaches and the preliminary nature of the findings reported on here, our findings raise deeper questions for engineering education scholars and practitioners as well as game-based learning designers: How do we bridge the gaps in learning created by differences in prior gaming experience? How can we support women engaging with *GeoExplorer* and other game-based learning environments in improving their efficacy beliefs related to their ability to apply and transfer knowledge and skills gained in the virtual environment? What are our next steps in investigating and designing game-based learning experiences for students of all genders?

We invite engineering education audiences to join us in grappling with these questions further through larger quantitative and mixed-methods studies, engaging larger and more diverse student populations. This paper aims to raise more questions and join a larger conversation about diversity, equity, inclusion, and access in engineering education.

Acknowledgment

This material is based upon work supported by the National Science Foundation (DUE-1431838 and DUE-1915247). We would like to thank Jaclyn Ho'24, Raúl Frías Pérez'24, Sydney Chung'24, Grant Goodall'24, Keanu Richards'24, Casey May'22, and Mason Grabowski'22 for their original contribution towards these data analyses and sense-making.

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