WIP: Investigating Students' Emotions and Motivations in a Game-Based Learning Environment

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***Abstract*—In this Work-in-Progress Research Paper, we explore students' emotions and motivations in a game-based learning (GBL) environment. GBL has been shown to be effective in improving students' cognitive and non-cognitive learning outcomes, including emotions and motivations. In this study, we focus on the Cone Penetration Testing module of *GeoExplorer*'s virtual learning environment, which has been shown to enable civil engineering undergraduates to develop key competencies necessary to problem-solve and make critical on-site decisions. This paper examines the impacts of *GeoExplorer* on students' emotions and motivations by asking: (1) How, if at all, do students' self-reported emotions shift through experiencing *GeoExplorer*, and how does *GeoExplorer* contribute to these shifts, if at all? and (2) What is the connection between students' self-reported emotions and their self-reported motivational attitudes, both before and after they engage with *GeoExplorer*? Responses from 60 participants about their emotions and motivations pre- and post-engagement with *GeoExplorer* were analyzed. Inductive methods, including open coding and the constant comparative approach, were used to analyze the following emotions-based survey item: *Thinking about your experience over the past week in the course, what particular emotions and/or thoughts about the course both inside and outside the classroom stand out for you?* Deductive analytical practices, including closed coding, were used to analyze the following motivations-based survey item: *What factors contributed to your motivation over the past week in the course?* Consistent with literature, our preliminary findings indicate an interrelationship between GBL experiences and shifts in students' reported emotions. We also determine a link between these emotional shifts and motivational changes from pre- to post-engagement with *GeoExplorer*. It is the interplay of these three elements – GBL experience, student emotions, and student motivations – that is at the center of this work.**

***Index Terms*—Game-Based Learning, Emotions, Motivation, Self-Determination Theory**

I. Introduction and Literature Review

This Work-in-Progress Research Paper aims to understand the interplay between students' experience with game-based learning (GBL) and their affective and motivational outcomes relevant to such experience, a subject that is of paramount importance for the design and implementation of inclusive and equitable learning environments which serve diverse student populations. Wang and Zheng (2020) define GBL as "learning environments that involve digital or non-digital games to enhance students' knowledge and skill acquisition" [1]. While research on digital forms of GBL, which is the focus of this paper, is fairly new, current literature suggests that digital GBL has positive student outcomes that are far-reaching – from improving students' "conceptual understanding and argumentation skills" to building "intellectual openness, work ethic and conscientiousness, and positive core self-evaluation" to having "a significant and positive impact on student engagement and academic performance" [2][3][4]. Specific to the STEM field, Wang et. al (2022) found that "digital game-based learning had a moderately significant effect on students' STEM learning achievement" with "no significant difference" in benefit "between the studies for science, mathematics, and technology/engineering" [5].

In recent years, the interplay between emotions, or affect, – terms used interchangeably in this paper due to their interchangeable use in literature [6] – and game-based learning has become of increasing interest. For example, Wilkinson (2013) argues that "attention, memory and motivation are key, affectively influenced, interrelated aspects of game based learning" and that "principles from affective computing can assist" in higher-level cognitive processing. Ninaus et al.'s 2019 results "substantiate that the emotionally engaging nature of games facilitates learning" [7]. Sauborin and Lester (2013) in their study of middle school-aged children further determine that "good inquiry strategies" such as "gathering background information after formulating and testing hypotheses" are "correlated with positive affective" states. Furthermore, not only do "affective states such as flow and curiosity tend to have positive correlations with learning while negative states such as boredom and frustration have the opposite effect," but also, "game-based learning ... can simultaneously support learning and promote positive affect and engagement" [8].

Kiili et al.'s 2023 findings extend this work to argue that "the game's mechanics, challenges, and design features may be sufficient for fostering flow regardless of the content domain presented in the game... [and] educational games can engage learners in subject domains that might [otherwise] only interest some" [9]. These findings indicate GBL's potential to support students' interest and positive affective states as well as encourage better student learning outcomes.

Alongside Kiili et al., much recent work on effectiveness of GBL has also focused on students' motivations. Plass et

al. (2015), for instance, write that "core elements of game design, including challenge, curiosity, and fantasy, are thought to be intrinsically motivating for players," which, in turn, has been demonstrated to affect positive student learning outcomes [10][11]. However, these authors further warn that "even within a single class of students who are playing the same game, students will approach the educational game with different goals and motivations" and "different approaches may be needed to motivate these different learners" [10].

In this work, we aim to explore these interrelationships between students' experiences with GBL, affect, and motivation. We do so by using inductive approaches for understanding students' affective states and leveraging deductive methods to investigate students' motivational attitudes, relying on the Self-Determination Theory of motivation (SDT).

SDT is a psychological needs-based theory of motivation, which asserts that motivation is supported through the satisfaction of three psychological needs: competence (confidence in one's own abilities), relatedness (sense of belonging), and autonomy (willingness, volition, and choice) [12]. SDT organizes motivation into six types: (i) Intrinsic (e.g., "*I work because the task is interesting/I find passion in it*"); (ii) Integrated Regulation (e.g., "*I work because the task is part of my identity*"); (iii) Identified Regulation (e.g., "*I work because the task represents one or more of my core values*"); (iv) Introjected Regulation (e.g., "*I work because the task is tied to my self-esteem*"); (v) External Regulation (e.g., "*I work for reward and/or against punishment*"); and (vi) Amotivation (e.g., "*I am not motivated to work*") [13]. The motivation types associated with higher autonomy (Intrinsic, Integrated Regulation, and Identified Regulation) have been found to support students in "full functioning and wellness, at every age" [12]. Especially when it comes to intrinsic motivation, "learning [has been found to be] a natural accompaniment of these interest-driven activities" [14]. Yamauchi and Tanaka (1998) found that "as motivational types change from external to intrinsic regulation, the self-regulated learning process becomes more closely related to better self-regulated learning," meaning that students are more likely to continue integrating the learning process and the resulting learning when they are intrinsically motivated to learn [15]. As well, students who are intrinsically motivated to learn gain the additional benefit of improved performance, as measured by GPA. For example, according to Froiland and Worrell (2016), "the significant indirect effect of intrinsic motivation to learn on GPA via engagement, as well as the positive direct association between learning goals and academic performance, suggest that students will benefit from schools fostering intrinsic motivation to learn and learning goals" [16].

In this study, we focus on the Cone Penetration Testing (CPT) module of *GeoExplorer*'s virtual learning environment, which helps students learn about soil properties and structural integrity through simulating CPT field testing, including CPT truck driving to a study site, as well as data collection and relevant analyses. In our previous work, *GeoExplorer* has been shown to enable civil engineering undergraduates to develop key competencies necessary to problem-solve and make critical on-site decisions [17]-[31].

This paper aims to contribute to the existing educational discourse on the impact of GBL on students' affective and motivational outcomes by addressing the following research questions: (1) How, if at all, do students' self-reported emotions shift through experiencing *GeoExplorer*, and how does *GeoExplorer* contribute to these shifts, if at all? and (2) What is the connection between students' self-reported emotions and their self-reported motivational attitudes, both before and after they engage with *GeoExplorer*?

II. Methods

As part of a larger mixed-methods study, this project analyzes the survey responses from *GeoExplorer* activity implemented in 12 U.S. universities in 2021. Here, we focus on 60 pre- and post-*GeoExplorer* engagement survey response pairs from 60 engineering undergraduates at a variety of academic levels, with diverse self-reported racial/ethnic and gender identities (3 gender categories were reported: man, woman, or prefer not to say).

Between the pre- and post-surveys, the students engaged in the CPT module of *GeoExplorer*. Of importance to our findings is that this activity took place at the end of the semester for most students in the study, and all students engaged in this activity while taking a foundational geotechnical engineering course. For this paper we focus on the following survey items: **"Thinking about your experience over the past week in the course, what particular emotions and/or thoughts about the course both inside and outside the classroom stand out for you?** Please give specific examples of emotions (e.g., excitement; passion; frustration; boredom; etc.) and/or thoughts (e.g., clear course goals; alignment with personal objectives; need for project clarity; usefulness of discussions; broken/updated laboratory equipment, etc.)" and **"What factors contributed to your motivation over the past week in the course?** Please give specific examples of activities, interactions, emotions, thoughts, etc. that may have contributed to your motivation."

Students' responses to the emotions prompt were analyzed using inductive analytical practices. Five coders used a combination of open and in vivo coding strategies to develop the initial codebook. The constant comparative method was used to ensure robustness of the codes and their definitions. The initial coding was performed independently by each coder, followed by a detailed review of each coded instance with eventual arrival at an agreed-upon coding schema. In addition to open codes describing students' context and reflections on their learning process, ten emergent emotions codes were identified: 'Inspired' (e.g., "*Geotechnical engineering was never my career interest, but after this experience, I am willing to rethink that*"), 'Excited' (e.g., "*It was an awesome in-the- moment experience*"), 'Neutral' (e.g., "*The class is ok*"), 'Detached' (e.g., "*I felt more focused and keen to learn before a certain unit or back when classes were in-person*"), 'Bored' (e.g., "*Kind of boring online, rather do it hands on*"), 'Tired'

(e.g., "*Exhaustion - I would very much like this quarter to be over already*"), 'Stressed' (e.g., "*Stressed from assignment*"), 'Confused/Frustrated' (e.g., "*Sometimes it was frustrating in the game especially with driving*"), 'NA' (e.g., "*Determination and course clarity*," i.e., an instance when a response provided does not correspond to the affective part of the prompt or is nonsensical), and 'I Don't Know' (e.g., "*I'm not really sure*"). When a response included multiple emotions, double and triple coding was employed to capture all nuances of the student's experience. Grounded theory approach was used to further analyze the data, allowing for the identification of emergent themes relevant to students' emotional shifts and the factors influencing these shifts, particularly concerning their engagement with *GeoExplorer*.

To analyze students' motivations, we employed closed coding using the six motivational types from SDT. All 60 pre- and post-survey response pairs were initially coded individually by five coders, who then met to discuss 10 coded pre/post-survey response pairs. Upon discussion and agreement on coding practices, all 60 response pairs were re-coded individually by each coder. This process yielded an intercoder reliability of 94% and 97% for the emotion-related responses on the pre- and post-surveys, respectively. The intercoder reliability for the motivation-related responses was 81% and 82% on the pre- and post-survey responses, respectively. We recognize that the scholars' positionalities impact the interpretation of the student responses and of the codes themselves. To engage scholars' positionalities, which persisted after discussion, any code that was agreed upon by two or more scholars in the final round of coding was included in the analysis. We believe that our coding schema yielded robust results, given an unusually high number of coders and achievement of an acceptable reliability standard of 80% agreement on 95% of codes [32].

III. Results

Below, we share the results of our investigation of (1) the affective shifts students report in their pre- and post-engagement with *GeoExplorer* and attribution of those to the *GeoExplorer* experience, and (2) the comparison of these emotional shifts to the students' motivational changes.

A. The GeoExplorer Experience and Students' Affective Shifts

In both the pre- and post-survey responses, the most identified emotion was 'Excited.' Many students whose responses were coded with this code in both the pre- and post-survey expressed content enjoyment and engagement with their professor and/or classmates. One student said of their experience that the "professor makes the material enjoyable, and he has a good sense of humor, it's a fun class to be at and it helps keep focus and learn while he is teaching."

The second most frequently identified emotion, also in both the pre- and post-survey, was 'Confused/Frustrated.' In the pre-survey, students largely acknowledged a work overload, having to experience the class online, and a lack of clarity. One example is a student response that reads, "Mostly stress. Need more manageable work and better clarity and guidance from professors." However, unlike 'Excited' code, the reasons cited by students experiencing emotions coded as 'Confused/Frustrated' in the post-survey are not the same as those in the pre-survey. Instead of in-class stressors or poor experiences with professors, in the post-survey, many of the frustrations center on the *GeoExplorer* experience itself. These frustrations do not stem from the GBL approach or *GeoExplorer*'s content. Rather, the students reporting 'Confused/Frustrated' emotions cite the *GeoExplorer* experience to be lagging or buggy, with one student writing that "The game ran a little slow which led to some frustration." Overall, 'Excited' students explain their affective state in both the pre- and post-surveys as resulting from class-related activities, while 'Confused/Frustrated' students initially report class-related frustration and confusion, and *GeoExplorer*-related reasons in their post-survey responses.

Of the 60 students whose response pairs to the emotions-related question were explored, only 21 indicated the same emotional responses in both the pre- and post-surveys. 15 of these 21 students were found to be 'Excited' – the majority of these students cited such underlying reasons as "I get to learn and try out new things" and "the professor makes this course very interesting and engaging" in both the pre- and post-survey. While no single distinct pattern was determined among the remaining 39 students whose responses reflected emotional shifts, our findings indicate that most affective shifts are associated with the negatively charged affective states. Most students whose pre-survey responses were coded with one of the neutral/negatively valenced emotions codes, i.e., 'Neutral,' 'Detached,' 'Bored,' 'Tired,' 'Stressed,' or 'Confused/Frustrated,' remained in this group post-*GeoExplorer* activity. However, their explicit responses usually shifted from one code within this group to another, rather than into a group of codes with more positive valence, such as 'Excited' or 'Inspired.' For one student, this shift was from 'Neutral,' i.e., "I would like to learn more about geotechnical engineering," to 'Confused/Frustrated,' i.e., "I started to get frustrated while playing the game, but I did learn a lot while playing."

Of importance to this discussion is that we identified a decline in the quantity (word count), quality, and nuance with which students discussed their affective states in the post-surveys in comparison to their original responses. For instance, 14 pre-survey responses were double- or triple-coded, due to students' descriptions of multiple emotions, in comparison to only 6 post-survey responses featuring double or triple codes. While this may indicate survey fatigue or the end-of-the-semester timing of *GeoExplorer* activity, the fact that very few students discussed either their emotional response to the course at large or to their *GeoExplorer* engagement may have several possible explanations, ranging from students' resistance to engage with questions related to emotions in an academic context, to their unwillingness to engage with the survey, to a potential perceived tension in considering both the big and small factors contributing to their emotional state.

To investigate *GeoExplorer*'s role in the post-survey, response pairs were pared down to the 8 that explicitly mentioned the "experience" or "*GeoExplorer*," "VE" or "virtual

environment," "game" or "videogame," "CPT" or "Cone Penetration Testing." Of these, only 2 students discussed emotions outside of *GeoExplorer*, sharing in response to the emotions survey item, "Boring; video game switched it up a bit though" and "Happy, sad, Its been a tough week to say the least. I had to redo [*GeoExplorer* activity] on a friends laptop because it didn't save my data, so that was frustrating." While it is likely that some responses were focused on *GeoExplorer* exclusively due to the context in which students responded to these questions, i.e., post-*GeoExplorer* survey completion, the prompt invited reflection about students' past week in the course, not about *GeoExplorer* in particular. It is notable, then, that for 6 students, *GeoExplorer* was the sole focus of their response about their emotional state over the past seven days.

The fact that the remaining 52 student responses did not even mention *GeoExplorer* as contributing to their emotions leaves little to say about the explicit impact of *GeoExplorer*. While the GBL experience was predominantly a positively-charged emotional experience for some – as one student explains, "[it was] interesting to make some site investigation and CPT test," while adding, "I feel more like I can gain more skills about soil aspects in the course moving forward. Now, I feel super hyped," – the aforementioned frustrations with how the game ran in practice should not be neglected, either. The shortness of the responses and the aforementioned lack of their nuance makes drawing further conclusions challenging.

B. Students' Emotional and Motivational Shifts

Most pre- and post-survey motivational responses of the students who engaged with the emotions prompt pre- and post-*GeoExplorer* activity were coded for external regulation. We interpret this as an implication that most of these students were approaching the course in a way that allowed them to achieve reward, often in the form of securing "good grades," or escape punishment, which often presented as "not want[ing] to fail a class." Most of these students shared emotions that were coded for 'Detached,' 'Bored,' 'Stressed,' and 'Confused/Frustrated' as opposed to 'Excited' or 'Inspired.' We believe that the timing of this activity at the very end of the semester may have played an important role in the way students engaged with both the activity and the survey instruments – a time when the reward/punishment aspect of the students' more global motivation may well overshadow the situational aspects of their motivations related to the *GeoExplorer* activity itself. While 7 students who reported external regulation still expressed affect that was coded for 'Excited' – likely students who felt that the reward of a good grade was going to be achievable for them, – it is probable that many students would experience emotions with negative valence in response to the uncertainty of their upcoming final grade.

The students whose motivations were coded for amotivation and identified regulation reported the largest diversity of affective states. We conjecture that for these students, the relationship between their motivation and their emotions cannot be evaluated due to the lack of motivation toward learning in the specific context. In comparison, for students whose responses were coded for identified regulation, a type of motivation that centers on one's values, these values may or may not be aligned with the *GeoExplorer* activity's goals and the ensuing affective states are representative of these potential alignments or misalignments. Additional data are required to understand the relationship between students' affective states and their *GeoExplorer*-related motivations.

The most common emotion-motivation pairing, that of identified regulation and 'Excited' affective state, was reported by 10 students in the pre-survey. We conjecture that students who know what they value and see that value being represented in what they do may be more likely to report excitement about their course activities. As one student in this group wrote in their pre-survey, "I enjoy this course inside and outside the classroom. I don't get a negative feeling about going into the webex meetings for class. She teaches it well and I feel confident in each step we learn."

While the most frequently established motivation-emotion pairing was that of identified regulation-'Excited' in both the pre- and post-surveys, three other pairings comprising 6 students each indicated additional patterns of interest in the post-survey: (1) intrinsic motivation-'Excited;' (2) external regulation-'Neutral;' and (3) external regulation-'Confused/Frustrated.' These pairings might be explained in the following way: being motivated through one's interest in the subject, whether *GeoExplorer*-specific or not, could lead one to feeling 'Excited,' while seeing the world as being full of rewards and punishments could easily lead to feeling 'Neutral' or 'Confused/Frustrated' after engaging with an activity that serves as a direct reminder of one's academic and career paths. As before, additional analyses are necessary to engage with context and content of what students share in their survey responses and understand the ways in which *GeoExplorer* affects students' affective states and motivational attitudes.

IV. Conclusions

This work serves to contribute to a broader understanding of the complexities of GBL environments' design and implementation and their impact on students' emotions and motivations. The increasingly growing rate of GBL adoption in STEM classrooms means that increasingly more diverse student populations engage with this learning environment, and it is imperative that we do right by these students. This paper aims to further research on GBL's ability to engage students who come from a wide background of motivations and emotions in learning. Our future work will explore the full survey data set, which contains 1,372 responses that span pre- and post-pandemic years (2020-2023). As well, data triangulation using student and faculty interviews will be performed for a more nuanced understanding of students' affective and motivational outcomes relevant to GBL environments.

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