Exploring Engineering Student's Self-Regulatory Strategies in Collaborative Virtual Reality Learning Environments: Preliminary Findings from a Land-Surveying Task

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***Abstract*— This work-in-progress research study explores students' self-regulated learning (SRL) strategies within collaborative virtual reality (VR) environments in engineering education. Through thematic analysis of responses from twenty-seven (27) second-year civil engineering students engaged in VR-based land surveying activities, key themes emerged related to goal setting, environmental structuring, help-seeking, task strategies, and self-evaluation. Students with high SRL scores demonstrated greater use of task strategies and self-evaluation techniques, while those with low SRL scores relied more on environmental structuring. The findings underscore the importance of tailoring VR learning experiences to students' individual SRL abilities and integrating features that promote social interaction to enhance collaborative learning and engagement. Future research will explore larger sample sizes and examine the relationship between SRL strategies and learning outcomes in VR environments.**

Keywords*— *Self-Regulated Learning (SRL), collaborative learning, virtual reality (VR), Land Surveying

I. Introduction

Virtual reality (VR) simulates real world scenarios in virtual spaces and enables participants' interaction within the virtual environments through their senses [1]. The implementation of VR in educational settings, particularly in engineering education, is increasingly popular in recent years because of its many affordances such as supporting experiments that may be impractical, expensive, or risky to implement in real-life.

Additionally, VR supports interactive and collaborative learning, particularly in distance education, by creating a virtual presence that allows students from multiple locations to interact and learn together as if they were co-located [2, 3]. This interaction not only enhances learning but also fosters a cognitive engagement [4] and sense of community among students [5] even when students lack access to physical labs.

Past research suggests that the use of VR for facilitating instructions could enhance students' engagement, creativity, and learning outcomes in engineering education [6, 7]. For instance, Ghazali et al. [8] conducted experiments with first-year electronics engineering students to evaluate the impact of VR on learning electromagnetism revealed that the integration of VR leads to better understanding and problem-solving skills. In other studies, VR has been used to support teaching engineering statics [4, 9], biomedical engineering concepts [10, 11], and land-surveying [1, 5]. The studies revealed that VR potential could be maximized to enrich students' learning experience and hands-on skills within the engineering discipline.

Unfortunately, investigating students' learning experiences in VR platforms poses a unique and complex challenge compared to other online learning platforms such as massive open online courses (MOOCs), online forums, and chats. Beyond the potential isolation resulting from the physical absence of peers or instructors, particularly when the students are accessing the platform from different location [12], and distractions from factors unwanted noise and external alerts [13], students may easily become distracted by the virtual world such as avatars [14], potentially diverting their attention away from the intended learning objectives and towards the novelty of VR technology itself. Hence, to maximize the use of collaborative VR for teaching engineering concepts, it is important to understand the strategies the students employ to mitigate the challenges and distractions they encounter during the learning activities.

In this study, we present our preliminary findings of the experiences of students participating in a collaborative VR activity based on the perspective of Barnard et al's [15] study on self-regulated learning (SRL) theory. This is important to serve as basis for future research that aims to provide insights for engineering instructors and faculty interested in leveraging VR, specifically in designing collaborative learning activities that accommodate students with varying levels of self-regulatory abilities. Specifically, we aim to answer the research question: What self-regulated learning (SRL) strategies do students describe using during a collaborative VR activity?

II. Literature Review and Theoretical Background

A. Collaborative learning in VR

VR technology offers affordances that make it suitable for fostering collaborative learning, including knowledge construction, resource sharing, skill acquisition, and social interaction [16]. Collaborative learning within VR environments has been vital for education because of its potential to improve educational outcomes through interaction between learners to achieve a shared goal [17, 18]. It enables learners to work together on a specific task, fostering mutual engagement of students in groups supported by VR technology.

Engineering education field has also increasingly embraced and integrated VR technology to teach and support collaborative learning in automotive [19], marine [20], civil [1], and architecture [21] education. For example, Shen, et al. [20] observed an increase in students' professional ability as marine engineers after usage of a marine engine room multi-user VR tool. Additionally, students in their study reported the tool to be interesting and effective for self-learning towards their professional formation. Similarly, Zhang and Chen [21] observed a positive effect on student engagement, interest, critical thinking, and building layout understanding in their use of a collaborative VR construction tool.

While collaborative VR presents significant opportunities for enhancing engineering education, its full potential remains untapped due to a lack of integration of learning theories such as self-regulated learning into VR instructional design. Optimizing the effectiveness of collaborative learning in VR requires the development of cognitive and socio-cognitive learning outcomes in learners which can be achieved by leveraging existing learning theories.

B. Self-regulated learning theory

Self-regulation plays a vital role in shaping students' experiences within collaborative VR platforms. Self-regulated learning skills enable students to control their learning processes by setting goals, monitoring their learning process, and adjusting their learning strategies. When learners are self-regulated, they independently control and monitor their learning processes through their self-management behaviors [22, 23]. Past studies have also linked students' self-regulation skills to their academic achievement [23] and to the motivation to learn [24].

SRL theory [27] enhances understanding of the learning experience from the students' viewpoint, particularly in VR platforms where there may be minimal or no teacher guidance and where a high level of self-regulation is required by students to fully capitalize on collaborative VR's potential for effective learning [25]. By focusing on how learners are empowered to regulate their own learning processes, SRL theory becomes particularly relevant in self-paced or less instructor-driven virtual environments.

In this study, SRL will be defined according to the study by Barnard et al. [15], which posits that the key component of online self-regulated learning consists of environmental structuring, goal setting, help seeking, task strategies, self-evaluation, and time management.

III. Methodology

A. Study participants and context

The participants for this study are second-year students registered in a mandatory geomatics and surveying course for civil engineering majors at a public R1 university in the southeastern United States.

During the course, the instructor employs a virtual total station to support specific land-surveying exercises. After presenting the task instructions in class, students pair up to engage in VR-based land surveying. They access a desktop VR platform, depicted in Figure 1, which mimics the functionality of a total station and recreates a typical land surveying setting. Within this VR learning environment, students practice land surveying using the virtual total station in a manner akin to real-life scenarios. The student pairs spent approximately 20 minutes completing the collaborative VR tasks.

Figure 1: Screenshot of VR Land Surveying Platform

B. Data collection and analysis

We received institutional review board approval for this study. This study data was collected during Fall 2023 semester. Ninety students participated in the collaborative land-surveying activities and responded to both a SRL Likert-scale questionnaire and open-ended questions after the activities. This questionnaire included items adapted from existing scales online self-regulated learning questionnaire (OSLQ) [26] while the open-ended questions include questions such as: Tell me about any distractions you experienced during the VR activities? If so, what are the sources of the distraction and how did you cope with the distractions? Also, what other obstacles or challenges did you encounter during the VR activities? How did you cope with them?

We distributed participants' self-regulation scores along a normal distribution curve to determine "high," "medium," and "low" categories relative the mean response, where high and low categories fall one standard deviation above the mean and one standard deviation below the mean respectively. While our complete dataset is comprised of 90 responses, we only analyze responses to the open questions from 27 students for this work-in-progress study. We anticipate linking both the quantitative data from Likert- scale responses and qualitative data from responses to open-ended questions for a future research paper.

Using our distribution, we categorized 14 students as having high SLR scores and 13 students as having low SLR scores. The scores of the remaining 63 students (not analyzed for this work in progress) were within the medium category. Our decision to prioritize examination of student scores in the high and low extremes gives us initial insights into the dataset that we will use for future work. A comprehensive analysis of the entire dataset, encompassing students falling in the medium category, is being planned. The demographic distribution of the 27-student subset is 85% male and 15% female. The majority of participants were White (85%) while others were Asian (11%) and Black (4%).

We utilized thematic analysis to deductively code students' responses to the open-ended questions. Thematic analysis allows for identification, analyzing and reporting patterns in a set of qualitative data [27]. The responses were coded deductively based on SRL [26] theoretical framework. Each response could be assigned multiple SRL codes to capture the multifaceted strategies students employed.

IV. Results

We systematically categorized 27 students' responses into themes which included goal setting, external structuring, help-seeking, tasks strategies, and self-evaluation. Time management from the SRL theoretical perspective [15] was not considered because it was not relevant to the VR activity's context.

A. Goal setting SRL theme

The responses underscore the need for clear standards and goals, the real-world relevance of VR activities, and the motivation to achieve objectives through learning experiences. The quotes revolve around the use of VR for experiential learning within the context of civil engineering. From the students' responses, the main difference between students with low SRL and high SRL scores is in the depth of VR's perceived value. While high SRL students see VR as an integral part of their learning, improving their engagement and comprehension, students with low SRL scores focus on VR as a logistical solution or a substitute for real-world experience.

Examples of the responses are given with parenthetical reference to their SLR categorization from:

"In civil engineering, exploring three-dimensional models of bridges, buildings, and infrastructure in a virtual space has significantly enhanced my comprehension of spatial relationships and design principles." (High SRL score)

"Because surveying equipment is so expensive and hard to access daily, I feel as if VR is a really good way to teach students surveying and help achieve the goal of mastering surveys." (Low SRL score)

B. Environmental structuring SRL theme

These quotes coded with the environmental structuring theme show students creating a focused study environment by choosing comfortable spaces, silencing phones, using headphones, or organizing quiet rooms, underscoring the importance of a conducive learning environment in the VR platform. The primary difference lies in the depth and thoroughness of the strategies employed. High SRL students tend to engage in more thorough and proactive measures to ensure a conducive learning environment. Low SRL students, while aware of the need to minimize distractions, often do not go beyond basic measures.

Samples of the quotes are given with parenthetical reference to their SLR categorization from:

"I organized myself for this by turning off all of my other devices, my phone, and then I put myself in my room by myself so that I could stay focused for the entirety of the activity." (High SRL score)

"In the age of technology, there are plenty of distractions, especially when using my computer where I'm constantly getting emails, and texts, and have a million tabs open with different schoolwork. I had to lock in and pay attention to the VR activity and ignore the distractions from notifications or my phone." (Low SRL score)

C. Help-seeking SRL theme

These quotes highlight instances where participants sought help, collaborated with others, and valued the support and interactions within the VR environment.

The primary distinction between students with low and high SRL scores in this context lies in their adaptability and perception of VR technology. While high SRL students often show a more proactive approach, finding ways to overcome challenges and extract maximum benefit from digital learning environments, low SRL students, in contrast, seem more focused on immediate challenges and express greater dependence on traditional instructional methods.

Some example quotes follow with parenthetical reference to their SLR categorization from:

"My interactions with my teammates were positive. Any suggestions, including how to work the software, were taken seriously and positively. This helped contribute to a smooth and inclusive learning experience." (High SRL score)

"There was no way to ask questions when we had them. For example, we couldn't get our point to calculate after lining up on the prism. We weren't sure if that was due to our station being off balance or if we were hitting the wrong button, and since we were all learning, there was no one with experience to ask." (Low SRL score)

D. Tasks strategies SRL theme

These quotes highlight where students describe specific approaches or actions they took to manage their tasks during the VR activities. While high SRL seem to better manage and even thrive under the independence that VR learning necessitates, showing greater adaptability and proactive engagement with the material, low SRL students focus more on the preparatory aspects of the learning environment.

Examples of the quotes with parenthetical reference to their SLR categorization include:

"There's no lecture, so I'm forced to interact with the material directly. I think with a class such as this one, the

VR format is perfect because it's all very low level and theoretical." (High SRL score)
"I took notes on the steps to follow from the video I watched at the beginning and then followed those steps during the Zoom and the VR activity." (Low SRL score)

E. Self-evaluation SRL theme

These responses illustrating the self-evaluation theme highlight the students' introspective and reflective approach to their learning process during VR activities. While high SRL student tend to overcome initial setup challenges more quickly and utilize VR's capabilities more fully, demonstrating adaptability and proactive engagement, Low SRL students emphasize difficulties in understanding VR's purpose and navigating the initial barriers to use, such as setup issues and lack of prior experience with the technology.
Sample quotes with parenthetical reference to their SLR categorization include:
"There's no one telling you what to do so if you aren't disciplined you won't get work done, however that could also be a good thing because it weeds out the people who aren't focused." (High SRL score)
"Learning in VR has the potential to be excellent; however, with no prior VR experience, it is hard to get started." (Low SRL score)

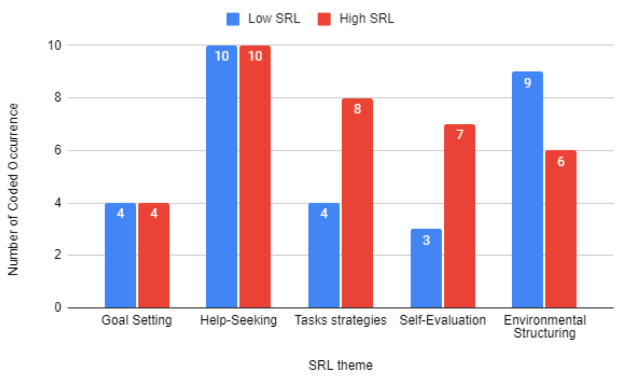

Figure 2: Distribution of student's SRL strategies in Collaborative VR

As shown in Figure 2, we coded an equal number of goal setting (4) and help-seeking (10) themes for both the low and high SRL groups. However, the high SRL group exhibited higher levels of task strategies and self-evaluation than the low SRL group. Regarding the environmental structuring theme, the low SRL group exhibited more of it than the high SRL group.

V. Discussion

The findings of this study align with practical perspectives, suggesting that students who are highly self-regulated tend to use task strategies and self-evaluation techniques to help them achieve their learning goals. Conversely, those with lower self-regulation may rely more on environmental structuring to ward off potential distractions during learning activities. Furthermore, analyzing excerpts from the student responses provides insights into specific self-regulated learning (SRL) themes. Educators should consider the varying levels of SRL among students when designing VR-based activities and should aim to create experiences that are not only relevant to real-world applications but also designed to foster deeper engagement for all students. Providing clear standards and goals for VR activities, along with targeted support for low SRL students, could help maximize the educational value of VR and ensure that it serves as a meaningful and effective learning tool for a diverse student population.

In terms of environmental structuring, students reported that they face distractions from phones, the internet, computers, and other sources. Therefore, their strategy for environmental structuring involves minimizing these distractions. This observation also supports the findings of Ashish, Kulshreshtha, and Borst [13], who note that though VR can boost student engagement and retention, factors such as stress, mind-wandering, unwanted noise, and external alerts can still lead to distractions and disengagement.

For their help-seeking strategies, Low-SRL students expressed concerns about the lack of help-seeking options available within the VR environment, highlighting a need for integrated support features. This finding is consistent with the study by Yang [28] which found that adaptive help-seeking strategies can influence students learning outcomes in online environment. Furthermore, it validates other past studies that posit that help-seeking is a vital learning strategy that positively associates with learners' academic achievement [29, 30].

The tasks strategies the students used during the VR include setting aside time, ensuring technological readiness, finding a suitable environment, and coordinating through online platforms like Zoom. These actions indicate a level of commitment and preparation for engaging in VR learning environment effectively.

The students use of self-evaluation strategies stems from their lack of prior experience with VR technology, confusion about the learning objectives of VR assignments, leading to uncertainty about the purpose and measurement of tasks within the VR lab.

VI. Implication of the Study for Practice

Based on our findings presented in this work-in-progress paper, engineering educator instructors that want to maximize the affordances of VR need to tailor their students' learning experience to match their individual SRL ability. For example, low SRL students may need a more structured learning environment such as distraction minimized area with regular check-ins while high SRL students may perform excellently in a more open-ended environment.

Furthermore, VR instructions should be designed to provide prompts, immediate and clear feedback, and answers to questions such as embedding virtual assistance or peer-support systems into the VR environment. This will help the students to access their understanding and adjust their strategies accordingly. Also, the role interaction was emphasized for achieving the VR learning objectives, hence, VR platforms should be designed to facilitate greater social interaction through integration of features such as social VR [31] that can provides engaging interaction for users.

VII. Limitations and Directions for Future Research

One limitation of our study is the diversity of our sample, which is confined to just one course. This might impact the transferability of our findings regarding students' self-regulated learning (SRL) strategies in other virtual learning environments such immersive head-mounted display (HMD) VR.

In our future study, we plan to include a larger sample that spans multiple courses to address this limitation. Our future research would also benefit from exploring more diverse samples across various courses to fully understand the breadth and depth of SRL strategies in different educational contexts.

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