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Virtual Reality for Second-Year Architectural Engineering and Construction Students: Exploring Flow, Experience, and Difficulty

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Abstract

Many engineering students are prone to the "sophomore slump," and require continued exposure to what engineers actually do and career development to maintain interest in their field. VR has the potential to engage students in real-world scenarios that are hard to access and visualize. In Architectural Engineering and Construction (AE/C), Virtual/Augmented-Reality-Based Discipline Exploration Rotations (VADERs) modules were created using real-world engineering scenarios to engage students in exploring the five AE/C subdisciplines: Acoustics; Construction; Heating, Ventilation, and Air Conditioning; Lighting; and Structures. These modules were designed to help students connect theoretical knowledge with practical applications and gain perspective on their field's scope and demands. In this study, second-year students at three different universities engaged with VADER-2 to complete discipline-specific tasks in a health clinic setting. The purpose of this study was to examine the extent to which VADER-2 engaged AE/C students in the learning environment. Students' perceptions of VADER-2 were assessed through post-intervention measures of students' self-reported flow (fluency and absorption in a task), overall learning experience, and perceived difficulty of the AE/C sub-discipline activities through both Likert-scale and open-ended items. Through k-means clustering of scale responses, four student clusters demonstrating significant differences in the measures were identified. Open-ended responses revealed that Cluster 4 students emphasized career insight, confidence, and enjoyment, while Cluster 1 students noted confusion and difficulty. Recommendations provide insight for VR/AR module design and use in AE/C programs.

Keywords: Virtual Reality, Augmented Reality, Architectural Engineering, Construction, Second-year

I. Introduction

Engineering plays a crucial role in solving real-world problems and driving innovation. Despite the importance of the field, as many as 50% of students who enter engineering programs with strong interest and enthusiasm leave their first major choice or do not complete a degree [1]. Institutions across the country have designed and implemented first-year experience programs that have gone a long way toward affecting student success [2]. However, many educators are wondering how students are doing in their second year, what sophomores need, and what responsibilities institutions have to design environments to meet those needs [2]. This matters because the sophomore year can be a turning point. Students experience the "sophomore slump" as they begin to further explore their reasons for attending college and become overwhelmed with their career choices [3].

A common expectation among incoming students is the opportunity to begin building and designing right away [1]. However, the initial years of most engineering curriculum are typically centered on general education and foundational theoretical coursework. As a result, the hands–on experience students anticipate, such as design projects or real-world problem solving, are often delayed until the final years of their academic journey, usually through internships or Capstone projects [4]. This discrepancy between expectations and reality can lead to decreased motivation, uncertainty about relevance of early coursework, and ultimately, decisions to switch majors or drop out. Sophomores need encouragement to take on responsibility for their learning. To optimize learning, designed environments can guide sophomores in ongoing, structured exploration of the world and of themselves [2]. Providing earlier exposure to practical discipline-specific experiences has the potential to enhance student engagement, deepen understanding of their field, and increase retention within engineering programs.

The demand for engineers is increasing in the United States and around the world [5]. The U.S. Bureau of Labor Statistics projects that employment in architecture and engineering occupations will grow faster than average for engineering from 2024 to 2034, with about 186,500 openings each year [6]. While AI is expected to automate routine activities (e.g., drafting, schedule analysis, early-stage design option generation) and transform AE/C work, there are shortfalls in qualified construction managers and engineers [7], and increasing project complexity will call for different skills including AI integration [e.g., 8]. These projections make it important for universities to help students not only enter engineering programs but also stay in them.

One contributing factor to low retention in engineering is the reliance on traditional, lecture-based teaching methods that emphasize abstract concepts over practical engagement. Most U.S. engineering programs emphasize traditional classroom instruction over hands-on experience, causing real-world exposure to be delayed until later in the curriculum [4]. While these approaches may support foundational learning, it often lacks interactivity and fails to meet the needs of diverse learning styles, especially for visual and kinesthetic learners [9]. When students cannot see how coursework connects to real-world applications, they may lose interest or confidence in their ability to succeed. This challenge is particularly relevant in fields like AE/C, where hands-on practice is essential but often delayed until later in the curriculum.

To address this challenge, VADERs (Virtual/Augmented-Reality-Based Discipline Exploration Rotations) modules were created to give students early exposure to the different subdisciplines of Architectural Engineering and Construction (AE/C) through interactive learning experiences. The modules place students in realistic engineering scenarios such as analyzing structural systems, managing construction activities, or navigating system controls (lighting, acoustics, mechanical) in virtual built environments. These tasks allow students to apply technical concepts in meaningful contexts. By incorporating these experiences during the sophomore year, when students may be navigating the "sophomore slump" and feeling increased pressure to define their direction [2], VADERs aims to strengthen students' connection to their field, build confidence in their engineering abilities, and ultimately improve engagement and retention in AE/C education.

II. Background

Virtual Reality Technologies in Engineering Education

Non-immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) are transforming the way engineering is taught. These tools offer students dynamic environments where they can visualize complex systems, simulate real-world situations, and learn interactively. In engineering, where concepts are often complex and spatial, these tools allow students to experience environments and problems that are otherwise inaccessible in a classroom.

Recent studies have explored VR/AR to teach specific topics such as structural analysis, simulation of compression testing, construction safety, equipment and operational task training, and sustainable building design in AE/C [10]. In civil engineering, VR tools (e.g., Revit, Sentio VR, and Resolve) have been used to support student creation and exploration of 3D construction-site models, which strengthened their spatial understanding, visualization skills, and software proficiency [11]. Students reported higher engagement and described VR's visual interaction making concepts clearer than traditional lectures [11]. A mixed-reality learning module used with civil engineering students similarly found that participants were engaged, demonstrated increased knowledge and confidence, and viewed the experience as valuable for gaining field experience [12]. In addition, a browser-based WebVR platform enhanced with wearable sensors improved classroom engagement with students reporting higher motivation, increased interest, and a stronger sense of control over their learning experience compared to those who received traditional video instruction [13]. These VR/AR interventions were able to stimulate students' interest, enhance their knowledge acquisition, and improve success in creative design and planning tasks by utilizing immersive visualization and student-computer interaction.

VR has also been used to support career exploration by helping students understand what professionals do in real work contexts. In a study using VR 360 career videos, students reported gaining career knowledge by noticing workplace tasks, recognizing the importance of different roles, and feeling more motivated to pursue certain careers [14]. In a simulated job experience, participants used more technical words and made detailed task descriptions after the experience, suggesting a clearer understanding of the profession [15]. These findings are directly relevant to VADERs, as the modules immersed students in realistic AE/C tasks, helping them clarify which subdiscipline aligns with their interests and, ultimately, making better career path decisions.

Importance of the VADERs project

The VADERs project offers students in Architectural Engineering and Construction (AE/C) programs access to non-immersive VR (nIVR) environments [16]. Meaning, it used regular computer screens (without headsets or wearables) and keyboards for navigation, The system was affordable and accessible, while still offering interactive simulations of engineering activities such as building walkthroughs, safety inspections, and construction planning.

By allowing students to experience these scenarios early in their academic journey, the project supports key outcomes like increased engagement, improved self-efficacy, and better retention in AE/C programs. As the construction industry continues to evolve with new digital technologies, the VADERs project introduces students to practical skills and builds the career interest needed to thrive in current and future demands.

III. Research Question

The primary research addressed in this study was: How do second-year AE/C students experience VADER-2 in terms of flow, experience, and difficulty?

IV. Methods

A. Setting and Participations

This study was set in AE/C second year courses during 2023 and 2024 at three universities including a R1 Midwestern institution (R1MW), R2 Southeast HBCU (R2SE), and a R1 Southeast institution (R1SE). These courses included AE-specific courses offered by the R1MW (Fall 2023) and the R2SE (Fall 2023 and 2024) and Construction-specific courses offered by the R1MW (Fall 2023and 2024) and the R1SE (Fall 2023). Of the 152 students enrolled in the courses, 106 students consented to participate, with 63 students retained in the study after exclusion criteria were applied (see Section IV.D). The demographic profile of the retained participants, as self-reported, was 68% male, 70% White, and 76% within the age range of 19-21 years. The number of participants from each institution and major are shown in Table 1.

Table 1. Self-reported Demographics by Cluster

Category	Subgroup	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
	Number of Students	**4 (6.3%)**	**16 (25.4%)**	**18 (28.6%)**	**25 (39.7%)**	**63**
Institution	R1MW	3	13	11	15	42
	R2SE	0	1	1	6	8
	R1SE	1	2	6	4	13
Major	Architectural Engineering	1	8	5	17	31
	Construction & Related	3	8	9	8	28
	Undeclared / Undecided/ Other	0	0	4	0	4

B. Intervention

VADERs were non-immersive virtual/augmented reality-based educational modules. The modules designed to help students explore the five subdisciplines AE/C: Acoustics; Construction; Heating Ventilation and Air Conditioning (HVAC); Lighting; and Structures. While VADER-1 module provided an integrated approach to help students better understand how these areas work together on real-world building projects [17], VADER-2 aimed to isolate the disciplines into distinct experiences more truly providing a “rotation” experience in each specialization. The interactive activities were also more advanced, aligned with students’ education level. Both VADER modules ultimately aim to help first and second-year students visualize themselves as future professionals in the AE/C field.

In VADER-2, students were hired as interns by a fictional company to work on tasks related to the design and construction of a health clinic. For each subdiscipline rotation (akin to medical residency), they completed a short training video and an interactive nIVR experience. Inside the nIVR environment, students rotated through the AE/C subdisciplines by visiting different clinic rooms and environments, listening to prompts from a virtual project manager, and exploring design challenges focused on issues such as patient safety, cost, and the performance of building systems. The ultimate mission of VADER-2 was to address a goal and a set of three (3) unique learning objectives (LO) for each of the five subdisciplines (Table 2).

Table 2. VADER-2 goals and learning objectives.

Rotation	Goals and Learning Objectives
Acoustics	Goal: Understand how building materials affect sound transmission and acoustics quality.
	1. List key elements of building acoustics 2. Estimate A-weighted decibel (dBA) & Noise Criteria (NC) ratings for three door options 3. Justify door selection by comparing estimated dBA & NC values to recommended levels and through listening experiences
Constructi on	Goal: Identify and understand the key stages of a wall construction process.
	1. Identify the tasks construction managers perform including initiation, preconstruction, procurement, construction, and close-out 2. Determine the correct sequence of construction for a reinforced masonry wall 3. Calculate the estimated cost to construct a concrete masonry wall
HVAC	Goal: Compare two common ventilation strategies and observe indoor air quality performance
	1. List the pros and cons of Mixing Ventilation (MV) and Displacement Ventilation (DV) systems 2. Apply energy balance equation to find the supply air flow rates for MV and DV systems 3. Justify a selection between MV and DV system based on the velocity, temperature and age of air in the space
Lighting	Goal: Design an efficient lighting layout based on brightness and glare criteria.
	1. Demonstrate how to use the zonal cavity method for a simple lighting design 2. Calculate the Room Cavity Ratio and the required number of luminaires 3. Calculate DGPsimplified and assess its differences from DGP
Structures	Goal: Understand how wall openings and layout affect structural response to earthquakes.
	1. Classify construction materials as ductile or brittle (material level behavior) 2. Explain in-plane versus out-of-plane behavior of masonry walls subjected to lateral loads (member level behavior) 3. Identify the relationship between the architectural layout and the structural behavior of the unreinforced masonry building under seismic loading (building/ system level)

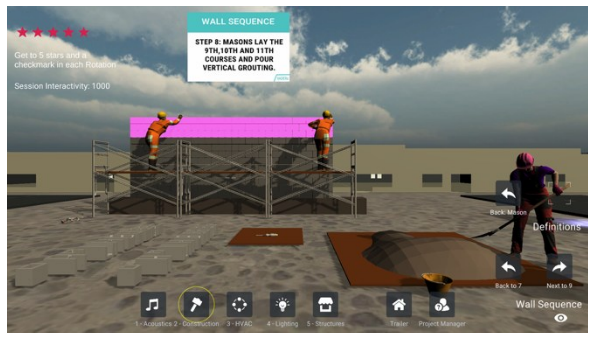
VADERs modules were delivered through a Free Canvas course. Table 3 outlines the main components of VADER-2 module, including their purpose, such as helping students apply knowledge, make designs decisions, and reflect on their learning experience. The Canvas's Module feature was used to establish a chronological order of steps, with pre-requisite requirements, guiding the students from one step to the other: Reflection A (beginning of semester), Reflection B (right before module), Pre-quiz, Introduction to module, Rotation videos, nIVR experience ("Virtual Clinic), Post-quiz, Final Deliverable submission, and Reflection C.

Table 2. VADER-2 module components

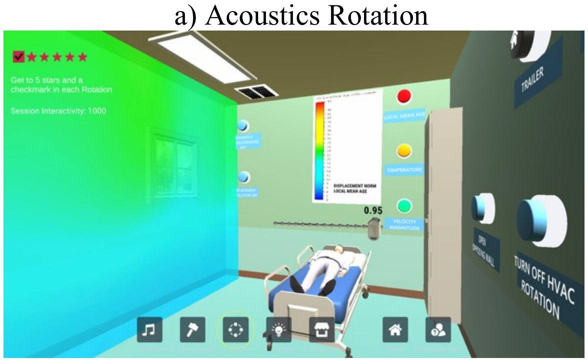
Assignments	Tool Type	Description
Introduction to Module	Canvas MP4 & PDF File	Overview of VADER-2 learning objectives (LO) and key components of the module
Timesheet	Canvas PPTX File	PowerPoint slide to log time spent on VADER-2 activities
Reflections A, B, and C	Canvas Link to Qualtrics	Pre-, mid-, and post-surveys used to assess impact of VADER-2
Pre- and Post-Rotation Quizzes	Canvas Quizzes	Assessment of learning of AE/C sub-discipline technical content within VADER-2; 2 questions per LO, 6 per rotation, 30 overall
AE/C Subdiscipline Rotations	Canvas Page: Canvas MP4 & PDF File	Content on subdiscipline LOs and tasks for each of the 5 rotations by watching a ~15min video
Virtual Clinic	Canvas Page: Link WebGL:niVR	Interactive niVR experience with each of the 5 AE/C subdisciplines in healthcare clinic.
Final Deliverable	Canvas PPT File	10-slide fill-in template to capture results and learning from the VADER-2 experience

Upon entering the niVR simulation, students began in a construction trailer where they received an overview of the VADER-2 mission from a virtual project manager. This construction trailer also included strategically placed personalized items (e.g. hard hat, diploma, desk name plate) based on the student's login information, to augment visualization of self in AE/C professions. From the construction trailer, students were provided with clearly marked buttons to teleport into each subdiscipline-specific environment and complete their assigned task. Each subdiscipline rotation (Figure 1) is a stand-alone experience unique to that subdiscipline, covering interactive activities related to each of the three LOs (Table 2). For each rotation, the LOs and related theoretical background were explained in a video viewed prior to starting the niVR experience. From each sub-discipline environment, the student could press a button to return to the main scene where they could select another rotation to complete. Each subdiscipline rotation is described below.

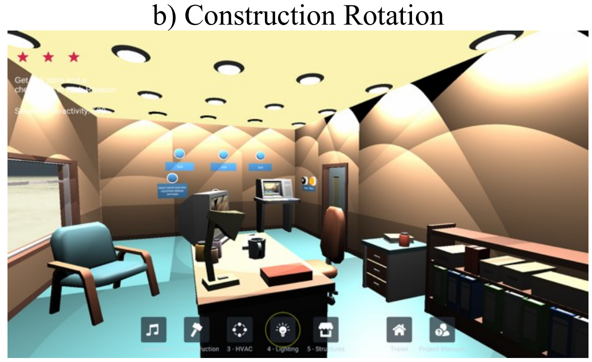
a) Acoustics Rotation

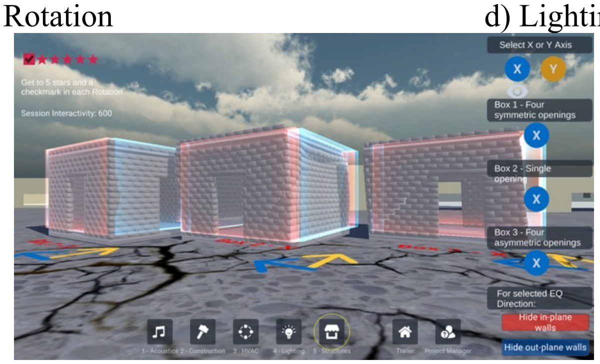


b) Construction Rotation



c) HVAC Rotation


d) Lighting Rotation



e) Structures Rotation

Figure 1. Images of VADER-2 Virtual Environments

In the Acoustics rotation (Figure 1a), students explored how different door selections impact sound transmission into a patient's room. By activating buttons on the walls, students listened to audio played through various door configurations and compared how much sound passes through. Additional buttons let students play different types of sounds, such as music or ambient noise, and hear how the experience changes based on proximity and door selection. The environment included visual heat maps that display sound intensity and floating spheres that illustrate sound wave propagation, helping students connect what they hear with how sound behaves in real spaces.

In the Construction rotation (Figure 1b), students followed a step-by-step sequence to learn how to build a reinforced masonry wall. By clicking through the interface, they reviewed construction terms and observed each phase of the process, from site preparation and foundation to wall reinforcement and completion. This guided simulation helped students understand the practical order of construction tasks and the terminology used in real-world job sites.

In the HVAC rotation (Figure 1c), students examined how different ventilation strategies affect air distribution in a patient's room. They activated Mixing Ventilation (MV) or Displacement Ventilation (DV) and observed differences in airflow patterns, temperature, and local mean age of air. A slider tool let students move a visualization plane across the room to see how air properties change at various points. Color-coded data displays and interactive buttons helped learners analyze velocity magnitude and thermal comfort, reinforcing key HVAC design concepts related to occupant health and energy efficiency.

In the Lighting rotation (Figure 1d), students explored how lighting design choices affect visibility and comfort in a staff office setting. They activated different options to observe how changing the luminaire height alters light distribution and how different layout configurations impact lighting uniformity. This interactive activity helped students understand core design principles used in electrical lighting for architectural spaces.

Finally, in the Structures rotation (Figure 1e), students examined how an unreinforced masonry building with different wall opening configurations (windows and doors) responds to seismic activity. They activated earthquakes in the X or Y direction for three box-shaped buildings with different types of openings: symmetrical and asymmetrical. Using interactive buttons, students highlighted in-plane and out-of-plane wall loads to understand how the orientation of the walls and the layout of the building influence structural behavior during an earthquake. By walking around and exploring the buildings, they compared the differences in failure modes, which highlighted the strong connection between initial layout (design) and structural behavior.

Throughout the module, students completed a timesheet to log the time they spend on tasks, which is a common way to report billable hours in AE/C firms. At the end of the module, students complete a PowerPoint presentation where they explain the decisions they made during each rotation and reflect on what they learned. Each rotation was ultimately designed to combine a traditional engineering task (e.g. calculation, table lookup) with a virtual interactive experience. Preparing a final deliverable enabled students to connect tasks they did in the niVR environment with traditional responsibilities related to that subdiscipline. The goal was to encourage them think like professionals and feel more confident about their future careers.

C. Data Collection

Reflections (Surveys) A, B, and C (Table 2) provided data for this study. Data were collected through Qualtrics at the beginning of the semester (Survey A), before students started VADER-2 (Survey B), and after they completed VADER-2 (Survey C). Each survey included a combination of multiple-choice questions, Likert-scale items, and open-ended questions. Of particular interest to this study were students' responses to the flow, experience, and difficulty instruments within Survey C. Each instrument is described below.

Flow Short Scale. Flow as defined by Csikszentmihalyi [18] is a state of absorption in an activity with an appropriate amount of challenge. A flow state occurs when one intensely concentrates on a task to the point of a loss of self-consciousness and a distorted sense of time passing while still feeling in control of the task and deriving satisfaction from the task itself. The Flow Short Scale (FSS) [19] assesses flow experiences in everyday tasks and educational settings using 10 items theoretically grounded in Csikszentmihalyi's conceptualization of flow [18]. These items loaded unambiguously on two factors: absorption (immersion in task) and fluency (effortless progress). The scale demonstrated internal consistency ($\alpha = 0.80$ for 4 absorption items, $\alpha = 0.92$ for 6 fluency items). While the factor scores can be reported separately, it was suggested that a total flow score can also be computed from all 10 items [20].

The FSS was adapted to the VADER research context. Three items were reworded: (1) "My mind is completely clear" became "I was not distracted from the activity I was engaged in", (2) "My thoughts/activities run fluidly and smoothly" became "I could navigate fluidly and smoothly through the virtual environments", and (3) "The right thoughts/movements occur of their own accord" became "The environment was responsive to the actions I performed." Further, the verb tense of all items was changed from present to past. The response format was modified from a partially labeled 7-point scale (from "not at all" to "partly" to "very much") to a 6-point strongly disagree to strongly agree Likert scale to avoid a neutral option. Content validity was ensured through a review of the items by multiple researchers including those with AE/C and engineering education expertise.

Psychometric analysis of the adapted FSS scale was conducted using responses from 320 first-year AE/C students completing VADER-1 in Falls 2023 and 2024. Exploratory factor analysis supported the two-factor model with acceptable internal consistency for the absorption factor ($\alpha = 0.80$) but weak internal consistency for the fluency factor ($\alpha = 0.59$). After removing one item ("I was completely lost in thought") due to poor loading and evidence in [19] that students were inconsistently responding to the item, the fluency factor showed improved reliability ($\alpha = 0.75$). A one-factor model excluding this item yielded the highest reliability ($\alpha = 0.87$), suggesting a unidimensional interpretation may be more appropriate as suggested by [18].

VADER Experience Scale. A VADER Experience scale was developed by the research team to reflect the intended outcomes of the VADER project. These items used a 6-point Likert scale ranging from strongly disagree to strongly agree. Psychometric analysis was conducted with 63 student responses from Fall 2023-2024. The scale included six items that loaded on one factor, but one item had a low loading. After that item, concerned with ease of navigation in the virtual environment, was dropped, the remaining five items yielded high reliability ($\alpha = 0.90$).

Rotation Difficulty. To capture students' perceptions of rotation difficulty, one survey item per rotation was created. The item was worded as, "Using the scale below, rate the difficulty level of each of the following VADERs rotations." The response options were provided as 5-point Likert scale where 1 = Too Difficult, 3 = Just Right, and 5 = Too Easy. Options 2 and 4 did not have specific labels. These in-between numbers allowed students to select a response that was between "too difficult", "just right", or "too easy.

Open-ended Prompts. In addition, Survey C included open-ended questions that collected qualitative feedback about the VADERs experience. Of interest to this stud, were students' responses to prompts that asked students to list three things they learned through the modules, to mention three ways the modules helped them understand AE/C, to describe what they found motivating, to suggest improvements, and to reflect on whether the experience reinforced or made them doubt their sense of belonging in the AE/C field. These open responses provided valuable insight into students' perspectives.

D. Data Analysis

The data was cleaned by removing the students who did not respond to all Flow, Experience, and Rotation Difficulty items. Additionally, student responses were excluded if they selected the exact same response option for every item, as this pattern likely indicated insufficient attention when completing the survey. After applying this criterion, 63 valid student responses remained.

Students' overall flow and overall experience scores were computed. K-means clustering was then performed using students' flow and experience scores. K-means clustering was used to identify clusters within the data with similar flow and experience scores. To identify the appropriate number of clusters (*k*), the Elbow method was applied using the *factoextra* package in R (open-source programming language for statistical computing and graphics) to quantitatively assess cluster compactness and separation. The aim was to determine the *k* value that minimizes within-cluster variance while maximizing inter-cluster distance. The k-value was then fed into the k-means algorithm using the *kmeans* function in R to determine cluster membership. The clusters were used in subsequent descriptive and inferential analyses.

Descriptive statistics by cluster were calculated for Flow, Experience, and Rotation Difficulty. The mean and standard deviation were calculated for each scale item, as well as overall. One-way ANOVA analyses were conducted to determine whether there were differences among the clusters for students' overall flow and experience scores and individual rotation difficulty. When a significant difference was found, post-hoc Tukey's Honestly Significant Difference (HSD) tests were performed to identify which clusters were significantly different.

An inductive coding process was applied to students' responses to the open-ended survey items. Responses were reviewed and coded to identify themes related to their perceptions of the VADER-2 rotations. The coded themes were then compared across clusters for deeper insight.

V. Results

Figure 2 shows students who rated their flow higher also tended to report a more positive experience. This figure also shows the four clusters that resulted from the hierarchical clustering analysis. Cluster 1 students (6.3%) reported the lowest flow and experience. They struggled to stay engaged and found the VR modules challenging to navigate or connect with. This group represents low engagement and limited immersion. Cluster 2 students (25.4%) also reported low flow and experience more than Cluster 1. Cluster 3 students (28.6%) reported medium-high flow and experience. They were more comfortable and engaged with VADER-2. Cluster 4 (39.7%) demonstrated the highest flow and experience. They were fully immersed, reporting strong focus and enjoyment while completing the VR tasks.

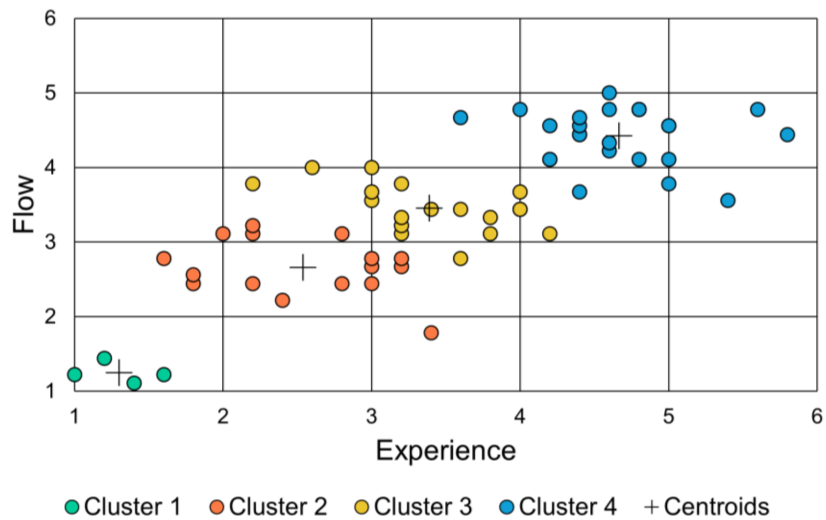


Figure 2. Students' flow and experience with VADER-2

Table 4 shows the mean and standard deviation of the item flow scores for each cluster and all students. Cluster 1 reported the lowest agreement across all items, indicating low absorption and low fluency; they had limited engagement, difficulty concentrating, and low confidence in navigating virtual environments. Cluster 2 also showed low flow levels. Cluster 3 reported more moderate agreement, indicating that the students felt challenged but capable. The students agreed that they felt just the right amount of challenge and felt they had everything under control. Cluster 4 showed the highest flow ratings. These students experienced the tasks as manageable and engaging. This allowed them to maintain focus and navigate smoothly in the virtual environment. The one-way ANOVA was performed on Clusters 2, 3, and 4 only due to the low number of students in Cluster 1. A significant difference was found among clusters for overall flow ($F(2, 56) = 118.40$, $\rho < .00001$). The Turkey's HSD test revealed that Clusters 2, 3, and 4 were significantly different from each other.

Table 5 shows the mean and standard deviation of the experience items for each cluster and for all students. Cluster 1 students reported the lowest ratings, showing confusion, low enjoyment, and weak connection to VADER-2. Cluster 2 showed slightly better understanding but still struggled to stay engaged. Cluster 3 reflected a moderate experience, finding the VADER project somewhat enjoyable but not fully immersive. Cluster 4 expressed the highest satisfaction and clarity, strongly agreeing that VADERs helped them visualize themselves as professionals and reinforced their sense of belonging in AE/C. A significant difference was found among clusters 2-4 for overall Experience ($F(2, 56) =83.25$, $\rho < .001$). The Turkey's HSD test revealed that Clusters 2, 3, and 4 were significantly different from each other.

Table 4. Students' Flow ratings for VADER 2 by cluster

Item	Flow Mean (Standard Deviation)[a]				
Cluster	**1**	**2**	**3**	**4**	**Total**
Number of students	**4**	**16**	**18**	**25**	**63**
I felt just the right amount of challenge.	1.25 (0.50)	3.13 (0.89)	4.00 (0.50)	4.52 (0.71)	3.81 (1.11)
I could navigate fluidly and smoothly through the virtual environments.	1.75 (0.50)	2.63 (1.09)	3.22 (1.22)	4.48 (0.77)	3.48 (1.32
I did not notice time passing.	1.00 (0.00)	2.38 (1.20)	3.00 (0.97)	4.16 (1.07)	3.17 (1.39)
I had no difficulty concentrating.	1.25 (0.50)	2.50 (0.89)	3.72 (0.96)	4.48 (1.00)	3.56 (1.35)
I was not distracted from the activity I was engaged in.	1.50 (1.00)	2.94 (1.00)	3.22 (1.17)	4.64 (0.86)	3.60 (1.35)
I was totally absorbed in what I was doing.	1.25 (0.50)	2.25 (0.68)	3.11 (0.68)	4.20 (0.71)	3.21 (1.15)
The environment was responsive to the actions I performed.	1.25 (0.50)	3.38 (1.20)	3.72 (0.89)	4.52 (0.92)	3.79 (1.26)
I knew what I had to do each step of the way.	1.00 (0.00)	2.31 (0.87)	3.06 (0.94)	4.36 (0.95)	3.25 (1.36)
I felt that I had everything under control.	1.00 (0.00)	2.44 (0.81)	4.06 (0.87)	4.44 (0.87)	3.60 (1.34)
Overall Flow	1.25 (0.33)	2.66 (0.18)	3.46 (0.22)	4.42 (0.13)	3.50 (0.99)

[a]Likert Scale: 1=Strongly Disagree, 6=Strongly Agree

Table 5. Students' Experience ratings by item for VADER-2 by cluster

Item	Experience Mean (Standard Deviation)[a]				
Cluster	**1**	**2**	**3**	**4**	**Total**
Number of students	**4**	**16**	**18**	**25**	**63**
The VADERs project was fun.	1.25 (0.50)	2.25 (0.93)	3.39 (1.20)	4.52 (0.82)	3.41 (1.42)
I understood what was expected of me for the VADERs project.	1.00 (0.00)	2.69 (1.08)	3.61 (0.92)	4.56 (0.77)	3.59 (1.33)
I wish more of my classes included interactive virtual environments like VADERs.	2.00 (1.15)	2.25 (1.00)	2.72 (0.96)	4.40 (1.12)	3.19 (1.45)
The VADERs project helped me visualize myself as an entry-level professional in the AEC industry.	1.75 (1.50)	2.63 (0.81)	3.56 (0.92)	4.88 (0.78)	3.73 (1.36)
The VADERs project reinforced my sense of belonging in the AEC industry.	1.00 (0.00)	2.88 (0.96)	3.67 (0.97)	4.96 (0.54)	3.81 (1.37)
Overall Experience	1.40 (0.68)	2.54 (0.10)	3.39 (0.12)	4.66 (0.21)	3.55 (1.16)

[a] Likert Scale: 1=Strongly Disagree, 6=Strongly Agree

In Table 6, students' perceived difficulty ratings provided insight into the challenge of each VADER-2 rotation. For all clusters, the HVAC rotation was rated as the most difficult, followed by Structures. The Construction rotation was rated as the easiest. Lighting and Acoustics were perceived as moderately difficult and closer to the "Just Right" range. Cluster 1 students reported the lowest mean ratings, indicating that they found most rotations more difficult than other clusters, except the Construction rotation. Cluster 2 students found most rotations to be slightly less challenging than Cluster 1 but still found the HVAC rotation to be very difficult. Cluster 3 students perceived the tasks as moderately difficult. Finally, Cluster 4 students rated the rotations highest, suggesting they experienced them as more manageable. Slight significant differences among clusters 2, 3 and 4 were found for Construction ($F(2, 56) = 4.33$, $\rho = .0178$) and Structures ($F(2, 56) = 3.35$, $\rho = .042$). For both rotations, Turkey's HSD results showed that only Cluster 3 and Cluster 4 were significantly different; Cluster 2 did not differ significantly. No significant differences among Clusters 2-4 were found for HVAC ($F(2, 56) = 3.01$, $\rho = .057$), Lighting ($F(2, 56) = 1.78$, $\rho = .179$), or Acoustic ($F(2, 56) = 1.93$, $\rho = .154$).

Table 6. Perceived Rotation Difficulty ratings by cluster

Rotation	Rotation Difficulty Mean (Standard Deviation)[a]				
Cluster	1	2	3	4	Total
Number of Students	4	16	18	25	63
Acoustics	2.50 (1.29)	2.56 (0.73)	2.89 (0.58)	3.00 (0.76)	2.83 (0.75)
Lighting	1.75 (0.50)	2.31 (0.87)	2.72 (0.75)	2.80 (0.87)	2.59 (0.85)
HVAC	1.50 (0.58)	1.69 (0.60)	2.00 (0.69)	2.32 (0.99)	2.02 (0.83)
Structures	1.50 (0.58)	2.44 (0.89)	2.06 (0.73)	2.76 (0.97)	2.40 (0.93)
Construction	4.25 (0.50)	3.44 (0.63)	4.00 (0.77)	3.32 (0.85)	3.60 (0.81)
Overall Difficulty	2.30 (0.34)	2.49 (0.13)	2.73 (0.07)	2.84 (0.09)	2.69 (0.41)

[a] Likert Scale: 1=Too difficult, 3=Just Right, 5=Too easy

The open-ended responses provided deeper insight into how students experienced the VADERs project among the four clusters. Each cluster's responses are described below.

Cluster 1 students expressed the most confusion and difficulty. They mentioned that the instructions were unclear and had difficulty with calculations. Still, they acknowledged that they learned about lighting, acoustics, HVAC, and structures. Their motivation centered mainly on completing the assignments rather than genuine interest in AE/C. A student mentioned, "*I was able to see/ understand more of the design challenges that engineers face but it was hard to navigate, I did not know what was expected of me, for the questions I didn't know what to solve for or what data to use.*" Cluster 1 students recommended improving the clarity of the instructions, improving navigation, and making material easier. As one student put it, "*The videos need more examples and easier concepts. The VR was too difficult to move around in, and it doesn't explain how to use each module.*"

Cluster 2 students also reported difficulty, but their responses reflected a slightly stronger awareness of AE/C disciplines. A student shared, "*The VADERs project may have reinforced my sense of belonging in the AEC industry because I found it to be interesting, so it gave me some hope because I know that I want to continue to pursue this career.*" They mentioned learning new concepts related to lighting, acoustics, HVAC, and structural analysis. Some recognized how calculations and design decisions relate to AE/C work. However, they described the project as confusing and disconnected from their coursework, often mentioning a lack of examples or guidance. While some appreciated the exposure to professional concepts, most felt the project needed clearer instructions, more calculation support, and to improve the quality of simulation. A student expressed, "*The VR experience was a little janky... I think that all the videos should have an example of what we are supposed to do/ calculate.*"

Cluster 3 students showed more positive engagement, explaining that VADER-2 helped them connect theory to practice and visualize how AE/C disciplines interact. One student reflected, "*It helped me visualize the different areas of engineering I could go into and gave me a little taste of what each one was like.*", while another noted, "*The VR gave me 'field experience' without being there.*" They mentioned learning new technical information in lighting, HVAC, structural, and acoustics, and that the interactive and visual components helped them understand how design choices affect real buildings. Many felt motivated by progress indicators and gaining career insight. Cluster 3 suggested improving content clarity, navigation, simulation quality, and calculation support to make the experience more engaging. One student wrote, "*I think the* *modules could be better; they did not always line up that well with the final deliverable. The overall experience felt a bit outdated. It also did not connect with what we were doing in class.*" Another recommended, "*A smoother VR game and giving more values for the HVAC problems.*"

Cluster 4 students demonstrated the highest engagement, confidence, and sense of belonging in the AE/C field. A student stated, "*The VADERs project reinforced my belonging in the AE/C industry as I was enjoying my time while doing the different tasks within this, this didn't feel like homework to me.*" They consistently described VADERs as enjoyable, realistic, and career-relevant, saying it helped them see how different AE/C subdisciplines connect and gave them a clear idea of what their future might look like. Another student explained, "*I could see myself working out issues in the field and enjoyed doing so.*" They valued the opportunity to explore realistic engineering scenarios using virtual reality, which made learning feel more authentic and motivating. Their feedback often mentioned the need for clearer content explanations, more calculation support, and further simulation improvements. A student suggested, "*To make the formulas more easily available, the HVAC and structural rotations were especially tricky due to constantly going back and forth between the equations and the tables.*"

VI. Discussion

The results suggest that student engagement in VADER-2 is closely connected to how students experience the module. Students who reported higher flow also tended to report a more positive experience. Meaning that when students felt focused and engaged during the modules, they were also enjoying the activity and seeing themselves as belonging in AE/C. This pattern supports the idea that flow can be a useful way to understand student engagement in niVR learning activities. The results also showed that about half of the students did not have overall flow or experience scores indicative of a positive experience (i.e., scores above 3.5 on both axes of Figure 2).

Rotation difficulty adds important context to these findings. Except for the Construction rotation, the students' rotation averages indicate they found them to be challenging (scores less than 3). AE/C expertise on the project team confirmed that, compared to the other rotations, the Construction rotation involved simpler concepts and computations. HVAC was perceived as the most difficult rotation across clusters followed by the Structures rotation. HVAC is a topic that students typically find conceptually difficult, particularly for construction management students [21]. Similarly, structures is considered one of the more difficult topics in engineering [22]. This matters because difficulty can shape flow: if a task feels too hard or unclear, students may lose focus; but if it feels manageable, students are more likely to stay engaged [18]. This relationship holds true particularly for Cluster 4 students who found the rotations the least difficult and had the highest overall flow scores.

Student feedback helps explain what may be driving these differences. Many students described VADER-2 as helpful for connecting course concepts to professional practice and understanding what AE/C work involves. At the same time, students pointed out several barriers that can lower flow, experience, and difficulty, such as unclear steps, limited examples, and the need for support for calculations. Some students also mentioned navigation issues, a feeling of outdatedness, or a lack of full alignment with what they were learning in class. These comments suggest that some negative experiences relate, to some degree, to how the activities are structured and supported in the AE/C courses. The selection of content for VADER-2 was challenging as second year AE/C courses across institutions can vary greatly. This variance presented a challenge for matching VADER-2 to an appropriate second-year course in each participating institution. Either all the subdisciplines do not fit with the course content or the content within a given subdiscipline may not be presented quite the way it is in the course. The disproportionate percentage of students in Clusters 1-3 that were in Construction (71%) versus AE (45%) majors may be a result of this misalignment.

Based on these results, there are some elements of the VADER-2 module and its implementation that can be further investigated. The goal is not to reduce a motivating level of challenge, but to better support students, so the difficulty level feels "just right". Identifying which instructions are not clear, what formulas need to be made more easily accessible, and what issues students believe they need worked example for may result in changes that could help students stay focused during the more difficult rotations. Working with instructors to improve alignment of the VADER-2 module with course content is also likely the best way to reduce frustration and help more students reach the higher-flow, higher-experience pattern seen in Cluster 4.

VII. Conclusion

In this study, students' perceptions of VADER-2 were explored using three measures: flow, overall experience, and AE/C subdiscipline rotation difficulty. The main takeaway was that clusters of students perceived VADER-2 differently, but flow and experience appeared correlated. Students who reported a more positive experience also tended to report higher flow, while students with the poorest experience tended to have the lowest flow. Across rotations, Construction was generally perceived as the easiest, while HVAC was perceived as the most difficult, and students in higher-engagement groups tended to see the rotations as more manageable overall. Student feedback helped explain these patterns. Many students said that VADER-2 helped them connect course concepts to professional practice and better understand what AE/C work can look like. Nonetheless, they also pointed out barriers that lowered their experience, such as unclear instructions, needing more support with calculations, and improving navigation. In conclusion, these takeaways suggest VADER-2 can support engagement and career exploration. However, tighter alignment between VADER-2 content and courses using the module may improve students' experience. Further investigation into improvements needed concerning clearer guidance, learning supports, and navigation, especially in the rotations students rated as the most difficult, may also be warranted.

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