Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46866

# BOARD # 79: Student-led VR Content Creation for Engaging Engineering Learning

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# Student-led VR Content Creation for Engaging Engineering Learning


## Abstract

This paper documents a student-led Virtual Reality (VR) content creation proof of concept funded as a Research Experiences for Undergraduates (REU) supplement to an existing NSF-funded project. The original NSF project focused on faculty professional development using a community of practice model to foster the integration of off-the-shelf VR contents in introductory STEM courses with the aim to enhance student engagement and improve STEM educational outcomes. A critical barrier identified amid the project was the lack of pedagogically sound, learner centered VR contents for the field of study in electrical and computer engineering (ECE). This REU project was then initiated by two motivated students who were enrolled in the redesigned, VR-integrated introductory ECE course, i.e., ECE90 - Principles of Electrical Circuits. Disappointed by the 3rd-party VR content they experienced, they went on teaching themselves VR content creation using the Unity game engine and C# programming language, developed a VR prototype (entitled MetavoltVR), and conducted user experience evaluation and learning assessment with peer students in ECE. As a proof of concept, this paper explored how student-led development of VR content and experience might offer a solution to a common obstacle faced by many STEM educators who are interested in exploring VR, which is the lack of readily adoptable VR content. This study contributes to better understanding the role and impacts of learner-as-creator/co-creator in engaging student learning in educational technology-integrated learning environments.


## 1. Introduction & background

The objective of this study was to explore student-led development of virtual reality (VR) applications as an alternative solution to enhance student learning and engagement in the field of electrical and computer engineering (ECE). The study was a supplemental work to expand the scope of the NSF funded project entitled "*Supporting Active Learning in Introductory STEM Courses with Extended Reality*" (Award #2126723). The original NSF project focused on faculty professional development using a Community of Practice model to foster endeavors in integrating off-the-shelf VR contents in introductory STEM courses to enhance STEM educational outcomes.

As reported in the research literature, the higher education space has witnessed increased use of VR, in conjunction with other reality technologies such as Mixed Reality (MR) and Augmented Reality (AR), collectively referred to as extended reality (XR). XR is reshaping learning experience and providing students with unprecedented learning affordance [1-3]. Reported benefits from the immersive learning experiences enabled by VR and other XR technologies include improving students' learning attitude and effectiveness [4], transferring students' self-perception [5], and increasing their identification with the STEM community [6-8]. XR also facilitates student-centered active learning to support students' retention of information, engagement, skill training, and learning outcomes [9].

Though the adoption of XR is growing, their applications still tend to focus on students using ready-made experiences, where students are the consumers, not the creators, of the XR experience [10]. The adoption of XR has generally been constrained by the cost of tools and software development as well as the narrow applications of XR, which tend to focus on narrow learning outcomes within specific learning areas, such as within medical education [11].

The research literature is confirmed by the NSF project experience, where a critical barrier identified and commonly reported by faculty participants in the XR faculty learning community was the lack of well-conceived, pedagogically sound, and learner centered VR applications and learning contents that could be readily integrated into existing STEM curricula [12]. Certain STEM disciplines, such as Biology, tended to have more commercially developed and established VR applications for immediate adoption. In the case of engineering, such as ECE, there were barely a handful of options with discontinued development and support. The two undergraduate student researchers involved in this study assisted in piloting the redesigned *ECE90 - Principles of Electrical Circuit*, with a 3rd-party VR application, i.e., Short Circuit VR, in the fall semester of 2023. Based on their own learning experience with traditional classroom lectures and observations of their peers learning with the Short Circuit VR application, they identified gaps in how the 3rd-party application lacked the affordance in facilitating authentic and contextualized learning experience to help lower-division ECE students master important and foundational circuit knowledge.

The two student researchers reflected that the Short Circuit VR application did not address how students would perceive and conceptualize engineering concepts and was limited in connecting visualization in VR with specific learning objectives. Therefore, they initiated this supplemental work and were determined to explore how learner-led development of VR learning experience might offer a solution to alleviate this barrier and contribute to better understanding the role and impacts of the learner-as-creator/co-creator approach in expanding the use VR-integrated learning environments in ECE field of study.

According to Iversen, et al. [13] and MacCallum [14], learner-led approaches in education have the potential to design learning processes that are meaningful for them, therefore provide additional benefits to engage and motivate learners. In the case of enabling students to create their digital artefacts, learner-as-creator/co-creator has been shown to provide greater engagement and outcomes as the potential for students to create their own immersive experiences also means that students move away from just being consumers of these experiences, and can become developers [15]. This approach motivates and empowers learners to apply a wider range of skills and knowledge to develop virtual artefacts and environments and supports cross-curricular learning where students not only develop their coding skills but also engage with a range of subject-specific knowledge in the process. Learning, therefore, happens in the development of the XR experience, not just its use.

In this proof-of-concept study, the two student researchers/developers demonstrated the process of custom-developing a VR application, entitled *MetavoltVR*, and conducted an initial investigation of its potential impacts on fostering peer lower-division ECE students learning fundamental concepts, principles, and analysis of electrical circuits in alignment with the ECE90 course learning outcomes. As a work-in-progress, this study collected preliminary user testing data from voluntary participation by peer ECE students to answer the following research questions (RQs):

- RQ1: How does MetavoltVR impact learning of electrical and computer engineering concepts and principles, in comparison with the third-party application, i.e., Short Circuit VR?
- RQ2: What are some of the advantages and disadvantages of student-led VR content creation in the context of this study?

## 2. Methodology

### 2.1.Research design

In a nutshell, a design-based research method was employed [16] that included the iterative development of the MetavoltVR application, testing of its implementation by a group of student volunteers, and assessment of its impacts on assisting students in learning subjects covered in ECE90. As an exploratory study that took place in Summer 2024, the learning assessment was conducted with a focus group instead of in a real classroom setting. Therefore, the assessment was mostly formative and qualitative, focusing more on understanding the multifaceted dependent variables that might affect the intervention development and capturing the social interaction [17] of its potential adoption before a more comprehensive evaluation could be conducted in ECE90 during the semester of Spring 2025. Students who participated in the focus group were less the “subjects” assigned to the “treatment”, i.e., MetavoltVR, but instead co-participants in both the design and the analysis.

### 2.2.Data collection and analysis plan

A portfolio of instruments was utilized to collect assessment data to address the two research questions. During the iterative development of the MetavoltVR application, individual students were invited to try out the initial (alpha) version of the application. Their feedback was captured with a pair of pre- and post-survey questionnaires and think-alouds, which was later factored into the next phase of development. Survey questionnaires were deployed via web URLs by the student researchers and descriptive statistics were performed. Think-alouds were recorded with the consent of the student participants and were transcribed later for thematic analysis. The complete alpha test for individual participants lasted about 40-50 minutes.

Toward the completion of the revised (beta) version of the MetavoltVR, a focus group were assembled with students who participated in the alpha testing to gather more comprehensive assessment data in comparison to the third-party application, i.e., Short Circuit VR, with open discussions on the opportunities and challenges, and overall viability of student-led VR content creation. The focus group included a 20-minute tryout of both the Short Circuit VR and the revised MetavoltVR applications, followed by a 30-minute semi-structured group interview (**Figure 1**). The complete process was recorded, and thematic analyses were conducted with the interview transcripts.

## 3. Results and discussion

### 3.1. MetavoltVR development

The first step in the development process was to determine what XR experience to construct for the intended learning activities. VR with the all-in-one Meta Quest 2 headset configuration stood out because of its ability to immerse the user in an entirely custom-built space fully controlled by the developers. In contrast, despite the advantages of being "contextual and authentic", AR or MR applications might distract beginners as the digital assets were usually augmented or superimposed on top of the real-world environment.

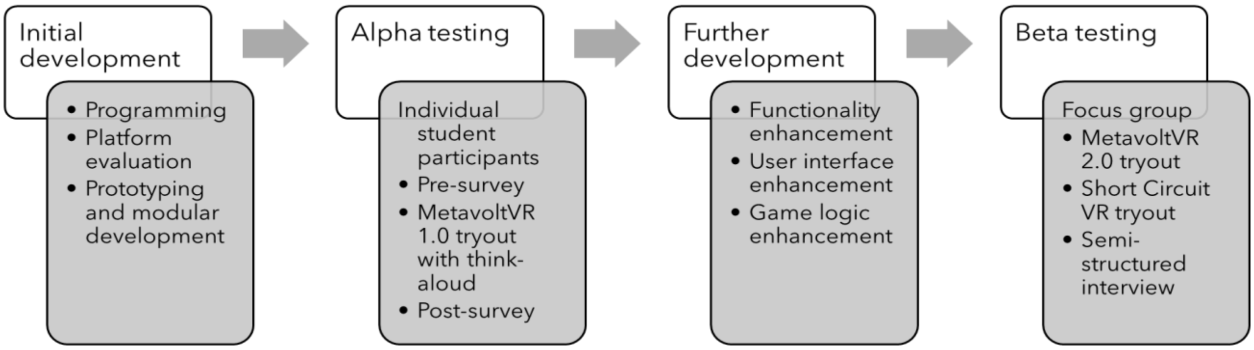
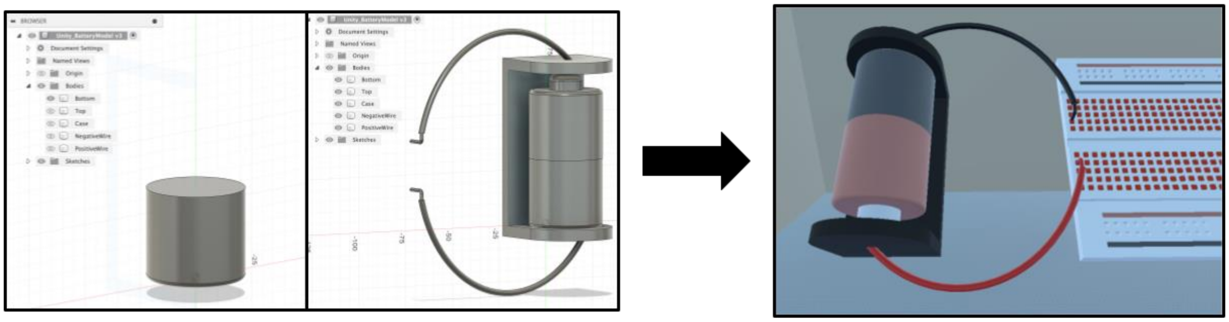



**Figure 1.** Research design and data collection.

The next decision was to determine what game engine to use to develop the application. Following the recommendations from the literature, choices were narrowed down to two main options, Unreal Engine and Unity. To ensure an informed choice was made, small test applications were developed using both platforms and were evaluated against benchmarks including a*pplication size*, *customizability*, *performance*, and *graphics*. The size of applications with the Unreal engine was significantly larger than the ones with Unity, indicating a larger storage and more processing power requirements for the headset to run the applications. The development environment of Unreal seemed more graphical, whereas the Unity platform allowed for C# scripts to be easily integrated into the application. For developers with a background in coding, Unity proved to be much easier to customize small details with. The performance of both gaming engines was sufficient, but the graphics quality of the Unity-based applications was significantly lower than the ones developed with Unreal. After analyzing both platforms, the developers found that customizability was the most critical factor to them, while the targeted audience and goal for the planned ECE learning application did not require top-of-the-line graphics. Unity was therefore chosen as the development platform.

A common challenge encountered in customized VR development was the need of 3D assets. Asset vendors such as the Unity Asset Store were searched when looking for circuit component assets for the application, and the developers found that there were no free asset packages of this type available anywhere. Therefore, all assets for the game had to be developed from scratch. The developers used Fusion 360 to design these components. This CAD software allowed each asset to be exploded into smaller functional modular parts, which was very helpful when assigning values to them in Unity. The assets were colored in Unity so that specific textures and overlays could be separately acquired from the Unity Asset Store and applied to each individual component. **Figure 2** below shows the lifecycle of one of the customized assets from design to in-app integration.



**CAD Development in Fusion 360** **In-app integration in Unity**

**Figure 2.** Lifecycle of an asset.

With the 3D assets, MetavoltVR's overall functionality largely relied on the gaming logic design and scripting with C# language. Though both student developers had a background in coding, neither had ever used the C# language before but had to teach themselves from scratch. The success of the two developers overcoming a knowledge gap in programming language was a strong testimonial to the idea of student-led XR development, as it showcased the viability of students with no background in game or VR development at all could learn enough on their own to develop a functional VR application in a matter of months. The first version of MetavoltVR took a total of seven months to develop, during which about 185 hours were spent working towards completion, as shown in **Figure 3**. The application was continuously tested throughout the development process using the Meta Quest Developer Hub software and a USB cable to connect and stream it to the VR headset. The ability to allow in-development testing with a target user interface within Unity was considered a huge advantage for XR development as it allowed the developers to test quickly and often, without idling time for downloading assets and data to the headset or the base computer. During testing, the in-development application was built and installed to the VR headset as an Unknown Source application so it could be accessed without a physical connection to the base computer, as well as without having to officially publish it to any commercial application stores.

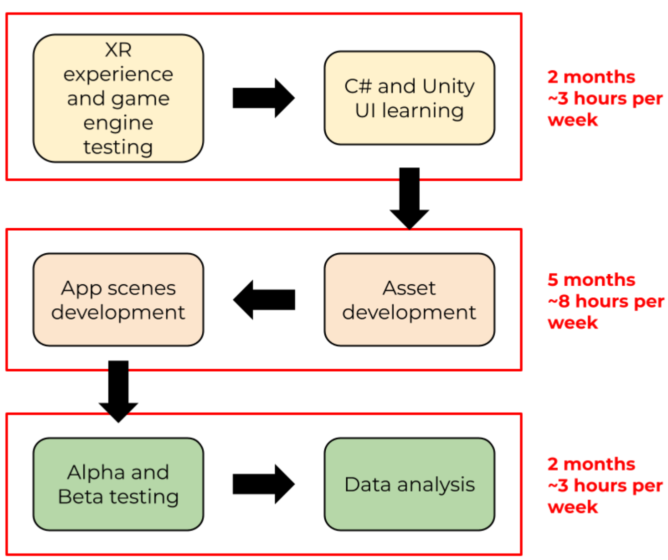



**Figure 3.** Development timeline and effort allocation.

The VR headset chosen for development and testing, Meta Quest 2, offered an all-in-one solution to affordable and reliable VR experience for broad integration into university classrooms. It also allowed for a seamless streaming connection to the base computer when testing during the development process. Meta Quest Developer Hub allowed wireless screen casting to be performed so that the user experience could be closely monitored throughout the alpha testing.

Additionally, an important part of maintaining an efficient development experience was the version control system (VCS) chosen to track changes throughout the process. GitHub Desktop was used for this purpose. This VCS allowed for concurrent changes made by both developers to the application from different machines and at different locations. The ability to record historical versions of the development provides crucial "knowledge memory" for later reference when designing repetitive parts of the app, as well as for helping other student developers create similar applications in the future.

### 3.2. Preliminary user testing

#### *3.2.1. Think-aloud*

The think-aloud was the main instrument for collecting feedback and evaluate user experience during the alpha test, and provided valuable insight into how peer students might feel about student-led VR development. The version of MetavoltVR used for alpha testing consisted of five (5) scenes/learning scenarios. These scenes were designed to teach the users basic digital logic principles, as well as allow them to explore simple circuit building. Seven (7) current undergraduate electrical or computer engineering students at Fresno State participated in the alpha testing using the think-aloud method.

Each of the users were tested individually, and all testing happened within a one-month period. The two main concepts conveyed to the users before they put on the headset were that they were encouraged to verbalize everything that they observed and thought, and that they had an unlimited amount of time to explore the application. The students chosen were diverse in personality and age, which caused the feedback amount and testing time to vary between students. The total time spent testing ranged from 15 minutes to 50 minutes, with an average testing time of about 27 minutes.

The reason users were encouraged to talk continuously was to ensure as much feedback as possible could be acquired. Generally, when using a new technology for the first time, engineering students tended to learn and explore quietly. This could cause them to overlook subtle details and only observe what they need to use the software. The think-aloud method encouraged them to look at every single aspect of MetavoltVR, which led to more valuable and insightful feedback. The users reflected that they felt more comfortable adopting the think-aloud method in the presence of the developers because the developers were fellow students, which constituted an advantage of student-developed applications. To regulate the user experience for reliable feedback, each user was tested with the same version of the application, had access to the same features, were given the same initial verbal instructions, and used the same VR headset.

The same scene exploration route was encouraged for each user, and that route started with the home scene (**Figure 4a**). At the home scene, several tutorial screens and simple activities helped the users learn the controls and introduced them to the topics they would learn in the other scenes. Since each control was customized for this app, any standard VR controls like squeezing the trigger for grabbing objects were not necessarily upheld. In addition to the in-app instructions, almost every user also required additional verbal instruction to fully understand the controls, and their preferences regarding the controls were analyzed in the post-survey questionnaire. After the tutorials, the users were encouraged to explore the digital logic scenes next, and finish with the circuit building scene. The users navigated each scene using the scene selector shown in **Figure 4b**.


**Figure 4a.** MetavoltVR In-app tutorial station.


**Figure 4b.** Scene selector tool.

To facilitate observation and data collection of user behaviors in this portion of the alpha testing, screen casting and audio recording were both employed. The screen casting consisted of streaming MetavoltVR output from the Meta Quest 2 headset to a base laptop so that the developers could see exactly what the users were seeing. This was crucial to ensuring that the developers could give useful instructions throughout the testing process. **Figure 5** shows the juxtaposition of the instructor perspective and student perspective, to emphasize the importance of capturing the screen cast. This data was only used during the testing session. The second data stream was audio recording. All oral communications between users and developers, and especially users' "think-alouds" were recorded and uploaded to Otter.ai for automated transcription. Once transcribed, the developers' dialogue was discarded so that the clean transcripts of users' narration in their think-alouds were saved. The cleaned transcripts were then imported into ATLAS.ti, where thematic analyses were performed to compare the observations and insights of all seven testers. **Figure 6** shows the data analysis process.

Several consistent themes were identified throughout the think-alouds transcripts from the alpha testing that indicated that engineering students responded positively to learning ECE-90 course subjects integrated in MetavoltVR. Over 100 clear feedback points were derived from the transcripts and were grouped into the main themes shown in **Table 1**. There were multiple times in almost every transcript that what student testers were observing in MetavoltVR would remind them of a specific course they had taken or software they had used in the past. This similarity was particularly significant in the digital logic portion, where the students mentioned the specific digital logic course number at Fresno State, and the software called Multisim that was used throughout the entirety of that course for them to construct and analyze digital logic circuits. The high relevance between MetavoltVR and existing ECE curriculum suggested that student-developed VR applications should have the potential to supplement and enhance student learning in ECE.

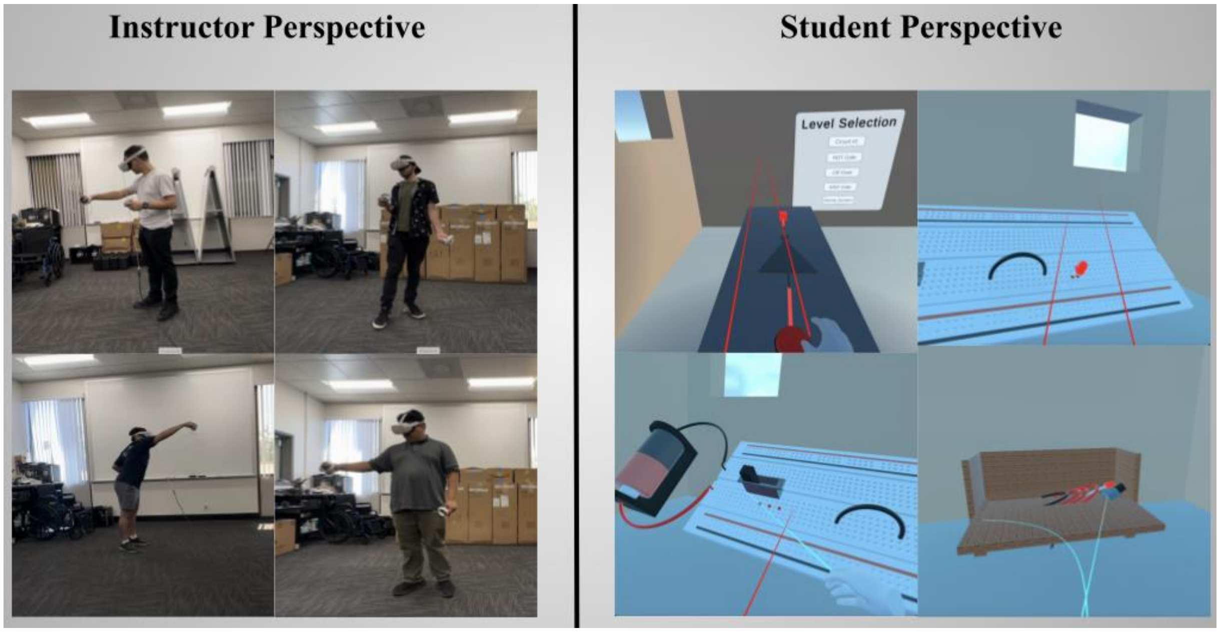



**Figure 5.** Instructor perspective vs. student perspective during alpha testing

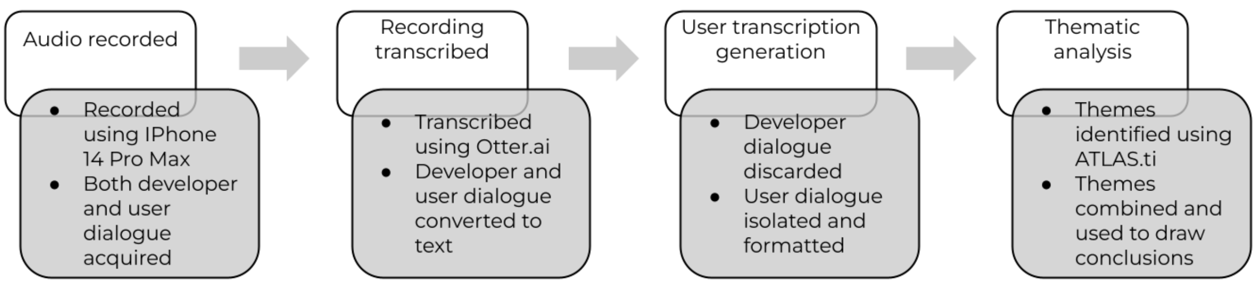



**Figure 6.** Quantitative analysis flow chart.

**Table 1.** Thematic analysis of think-alouds from alpha user testing.

| Sub-theme | Quote | Frequency |
|---|---|---|
| Course relevance | "...the app mimics the electrical and computer engineering degree that we all go through here." | 5 |
| Enhances learning | "...this is much better than writing material down or reading it in a slideshow." | 4 |
| Technology and game familiarity | "The video game feel is much more familiar to students…" | 3 |
| Connecting VR learning to real experiences | "...I saw it in Virtual Reality, so I will do it in real life." | 3 |
| In-app bugs | "The trigger squeeze causes a shake in the hand, which makes me select the wrong thing…" | 6 |

Other derived themes included students liking the more hands-on approach with MetavoltVR in comparison to lecture and presentation-based learning. Another interesting theme that arose was that the users felt that this way of learning was more familiar to them, since technology and video games are such a large part of their daily lives. The implication was that for certain concepts, MetavoltVR might be better at teaching engineering students than traditional teaching methods and could be used as a standalone tool in certain cases. The main negatives that were conveyed throughout the tests were related to in-app bugs, locomotion, and headset discomfort, which were all technical issues that could be solved with further development and alternative headset options. Overall, these results were very promising and shed light on figuring out how to modify and further develop MetavoltVR to appeal more to students.

#### *3.2.2. Survey questionnaire results*

As an additional data collection method during alpha testing, a pair of pre- and post-test survey questionnaires were administered and completed by all seven student testers with the aim to obtain more focused responses regarding their VR experience and background. The survey questions were developed using questions from similar research studies in the literature, e.g., Chalhoub and Ayer [18] and Wu, et al. [19], so that a clear picture of the unique impact of MetavoltVR could be assessed using proven prompts. The surveys were created using a software service called Jotform and were published on a custom developed public website dedicated to MetavoltVR. This method of survey construction was chosen to make the process seem more professional and important to the users, so that they might spend a little more time thinking about their responses and answering honestly. Each of the seven alpha test users completed the surveys independently right before and after their testing session.

The pre-survey consisted of questions asking each user about their previous experience with VR and their prior opinions regarding implementing VR applications into engineering classrooms. When asked about their previous experience with VR, 86% of the users said they had used VR before testing our app, but 100% of the users said they had no experience with designing VR applications. This meant that most of the users were already familiar with how to use VR but were completely new to the idea of student-developed applications. The users had mixed prior opinions regarding the helpfulness of using VR to supplement engineering coursework.

The post-survey consisted of several Likert rating scale questions asking the users about their experience with using MetavoltVR and asking them again about their opinions toward implementing VR into engineering classrooms. The rating scale used for these questions ranged from “Strongly Disagree (1)” to “Strongly Agree (5)” and were split into five intervals. **Table 2** shows the average and distribution of the user responses to three of the most important questions in the survey. The standard deviation (SD) for all three questions is quite low, which means that the user responses were quite consistent. Overall, the users reflected that using MetavoltVR was intuitive and smooth, even though they pointed out several bugs in the think-aloud portion. Most users also reflected that after testing MetavoltVR, they felt it could be easier for them to justify why VR could be a beneficial tool in engineering classrooms and believed that VR would be a helpful supplemental tool for them in their own learning experiences, especially compared with traditional lectures. This feedback was significant as it demonstrated a positive disposition toward student-led development of educational VR applications with immediate relevance to university curriculum.

**Table 2.** Average and distribution of post-survey responses.

| Question | Mean | SD |
|---|---|---|
| The app was overall easy to use and navigate. | 4.14 | 0.90 |
| Virtual Reality can be a beneficial tool in engineering education. | 4.57 | 0.53 |
| I feel like Virtual Reality would help me grasp concepts effectively if used as a supplemental tool in lectures. | 4.14 | 1.07 |
| Virtual Reality can be a beneficial tool in teaching circuitry to students. | 4.57 | 0.53 |
| Virtual Reality simulations should replace physical circuit building in electrical and computer engineering labs at Fresno State. | 3.00 | 1.41 |

The final question in the post-survey was asking users if they felt inspired to start learning VR development after experiencing MetavoltVR. This question aimed to probe a main hypothesized advantage of implementing student-led VR content creation, which was to inspire and empower other students to do the same. It was anticipated that when students witnessed the possibility and success of their peers who had no prior knowledge of VR development to produce a functional and meaningful VR application, it could make the process seem less abstract and daunting, but more accomplishable. The user responses (71.4 yea's and 28.6 nay's) reflected that many of them did feel inspired to develop their own VR educational applications after testing MetavoltVR, which supported the value and unique benefits of student-led VR content creation.

### 3.3.Focus Group

The focus group allowed the research team to directly compare students' perception toward the affordance and impacts of MetavoltVR with Short Circuit VR on learning ECE subjects (Figure 7). It also identified benchmarks that helped evaluate the obstacles and opportunities, and the overall viability of student-led VR content creation, as an alternative solution to promote VR-enhanced active learning for engaged engineering learning, instead of relying solely on third-party commercial VR content development.

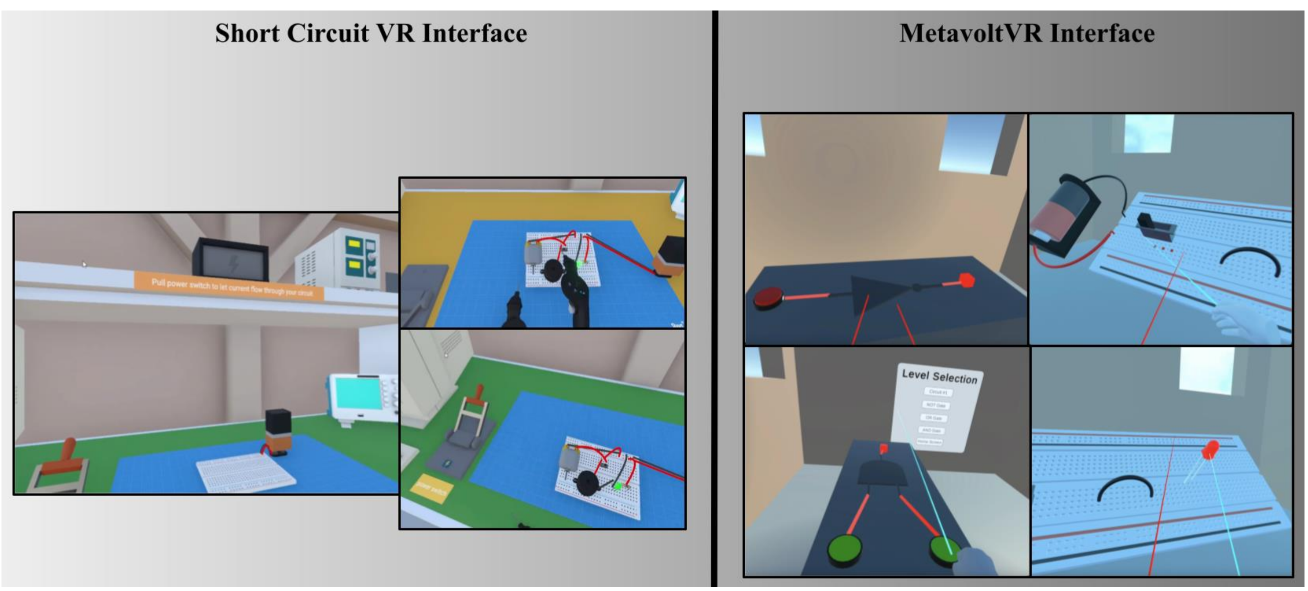



**Figure 7.** Comparison of the third-party app interface to the MetavoltVR interface.

The focus group consisted of four (4) of the seven (7) students who participated in the alpha testing. The students were given 20 minutes to experience each VR application individually, followed by a 30-minute semi-structured and guided discussion (**Figure 8**). The conversation was again transcribed using Otter.ai, and then transcripts were reviewed and rectified by all team members and imported into ATLAS.ti for thematic analyses.

**Figure 8.** Focus group beta testing setup.

Key prompts used in the focus group were catered to gather insights to answer the two research questions by inquiring participants' overall experience and perceptions toward the VR applications, their affordance for learning the target subjects, the perceived usability and design rationales, and finally, viability of student-led VR content development to promote its use in engineering education. The focus group provided the primary source of information to address the two research questions, which is elaborated in the following sections.

***RQ1. How does MetavoltVR impact learning in comparison with Short Circuit VR?***

Student participants reflected upon the learning affordance of both VR applications with a great interest in the rationale behind the application design, the relevance of the content and functionality to the learning subjects, and the ease of navigation within the virtual learning environments.

Students acknowledged the divergence of **design rationales** between the two applications, stating that "*priorities are different*." While the Short Circuit VR was programmed and developed for a generic audience, it was inevitably more general and broader, "*tuned towards a sandbox approach…it allows the teacher to have some more customizability*." In contrast, the MetavoltVR centered on specific concepts and knowledge points embedded in the coursework in the ECE curriculum, with a clear tendency to correlate and supplement classroom learning at the current institution. As students commented, "*it took a syllabus type approach and… mimicked the Electrical and Computer Engineering degree that we all go through here*." Therefore, much credit was attributed to MetavoltVR for its ***course relevancy*** and ***coursework supplementation*** considerations. Students regarded "*the point of this app is also to further grasp students' attention, to interest them beyond just the course material*," and they saw a potential that "*instead of teachers just lecturing from PowerPoints and students tuning out in class, they take that material that they're hearing from the PowerPoints, and then they work with it hands on.*"

When it came to **user experiences**, including the various user-interface (UI) features, Short Circuit VR was regarded as more polished with much thoroughly developed graphics and controls that promoted the sense of immersiveness. Nevertheless, students complimented MetavoltVR for its simplicity and classic controls that they felt "*a lot more similar to what you find from arcade or joystick game controllers*," thus "*general user interface and movement, definitely yours is better.*" Besides, students were frustrated with the trivial but constant buggy disruptions with Short Circuit VR, partially because of a much fancier and more computing power-demanding UI design and graphics, as reflected by students, "*that takes up processing power to generate that…it would be pretty streamlined, and there's some aspects of it that are really good, if this wasn't so buggy.*"

***Student-centered design*** and ***meaningful integration*** were unanimously identified as the biggest strengths of MetavoltVR in supporting learning, for obvious reasons. As the participants commented, "*You guys really just fine tuned on what you needed for this to be our actual coursework, and that's one of its strengths…the experience here by walking you through (is) like what we normally do with coursework.*" This "boutique" development was only possible because the student developers were knowledgeable of the learning subjects and were able to empathize with their peers on the nuances and contexts in which learning could occur. The participants reflected, "*(if) someone else do(es) it, who's never been here, they can't customize it that way…(for) commercial tools, they're focusing on making, typically, a profit and less learning.*"

***RQ2. What are some of the advantages and disadvantages of student-led VR content creation?***
Despite the unique strengths of MetavoltVR in supporting learning in ECE90, student participants, including the two student developers/researchers, reflected upon the viability of similar efforts in the future and variables should be factored into custom-developing VR content for more engaged and active learning in the field of electrical and computer engineering.

From a general VR application development standpoint, commercial development such as Short Circuit VR apparently represented a much higher standard level of care, including the UI sophistication and professionalism in its presentation, which constituted a key challenge for self-taught, inexperienced student developers. As the student developer reflected, "*something that I think we were also battling with making it was the combination, or the difference between professionalism and interactivity… the biggest challenge was not implementing our students' knowledge but creating an app up to the standards of a commercial one like Short Circuit VR.*"

On the other hand, student-led development, as mentioned above, excelled on the meaningful integration of not only learning contents, but also the way interaction was designed, and instructions were provided to scaffold learning among peer students so they could navigate potential learning challenges these student developers themselves encountered previously. As they reflected, "*we were trying to mimic the quality and the functionality of a commercial app, but also bring in our student perspectives that we have as current engineering students, currently taking the courses that we're trying to teach in this app.*" A summary of advantages and disadvantages of MetavoltVR and Short Circuit VR is shown in **Figure 9**.

A few key barriers identified by participants included ***technology barrier***, ***skill barrier***, and ***resources barrier***. Technology barrier referred to availability and potential costs of securing hardware (such as headsets and laptops) and software (such as game engines and 3D assets) essential for the development. The skill barrier was referring to the broad spectrum of skills involved in VR content creation without a dedicated educational or professional background in VR application development. The two student developers/researchers had to teach themselves C#, Unity, and 3D modeling tools before they could start the actual development. The skill barrier could be even more significant for students from a non-STEM or non-ECE background. The resource barrier highlighted the importance of time, lab space, and other resources invested in the development, testing, and production of VR content. The two students were able to conduct the development with the funding support from NSF and the summer break, with a lab space dedicated to such effort also funded through prior federal grants. To generalize and scale up similar efforts in the future, creative funding mechanisms, availability of human and financial resources, and other essential institutional support will be critical.

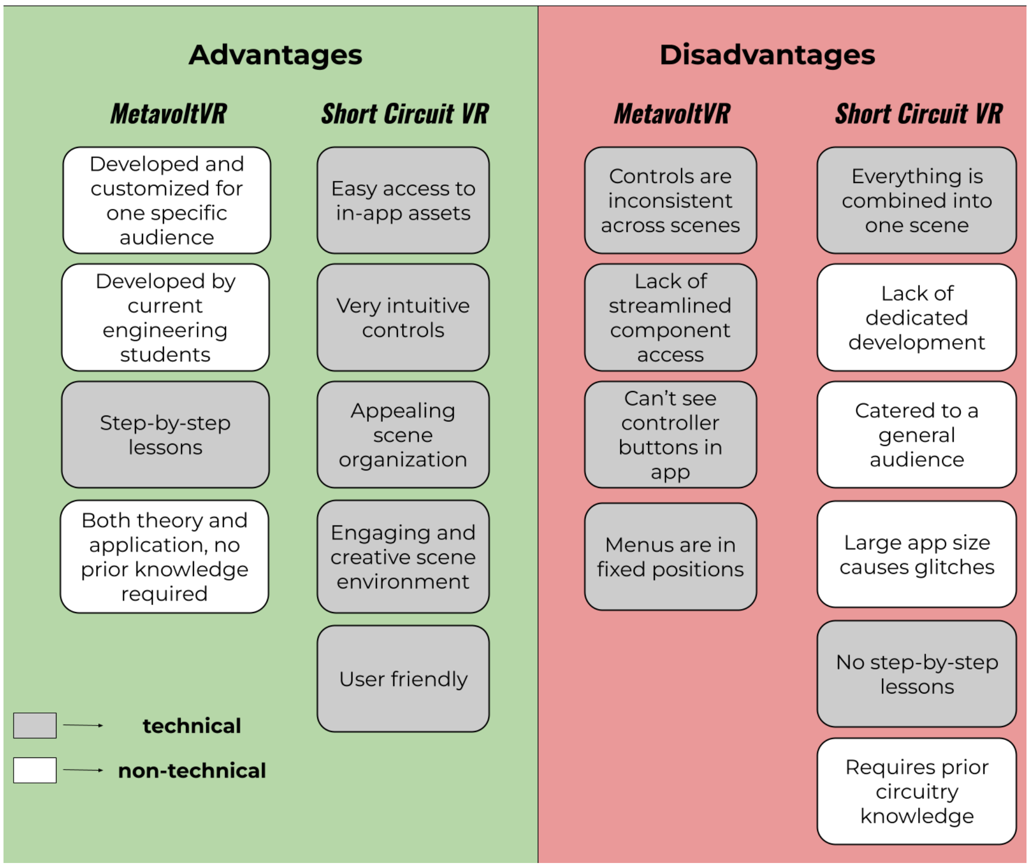



**Figure 9.** Advantages and disadvantages of each application according to focus group results.

Despite the challenges and obstacles, students felt encouraged to see an exemplar like this among their peers. As they commented, "*it's extremely interesting…this would be an incredible thing to learn.*" Students also suggested that establishing *a community of student developers* and maintaining good documentation of development logs could significantly contribute to viability and cultivating a culture of student-led VR content creation at the institution.

## 4. Limitations

There were two main limitations of this research study. The first was the fact that neither of the testing occurred in a classroom environment. The purpose of our testing was to determine how effective and well-received our application would be in engineering classrooms, and therefore the ideal place to assess that would be in an engineering classroom. This is the next step in the development process. Once all feedback is addressed and a 3.0 version of the app is ready, the developers will obtain permission from engineering professors at Fresno State to test the app in multiple introductory courses. This will allow for a larger test audience, and a more relevant setting, both be very helpful in further assessing the value of student-led VR content creation. A second limitation was that the scenes tested in the 1.0 (alpha) and 2.0 (beta) version of MetavoltVR contained only a fraction of the amount of material covered in an engineering course. This made it difficult for the users and developers to evaluate the impact this app could have on an entire course, because they only got to experience four basic exercises. Further development of this app means that additional exercises and concepts will be continuously added, and the developers will be in communication with several ECE faculty to figure out what parts of their courses could be enhanced with VR.

## 5. Concluding remarks and future research

This research endeavor demonstrated a proof of concept for student-led VR content creation in the context of electrical and computer engineering learning. Using design-based research, empirical evidence was gathered for evaluating the prototype, i.e., MetavoltVR, for its affordance of supporting active learning, and the viability of similar student-led VR content creation efforts in the future. Students who participated in the testing demonstrated positive experience with MetavoltVR and felt it would foster better learning for them in their courses, and therefore completely support the integration of future complete MetavoltVR in their courses as a supplement. The hands-on experience and contextualized interaction that VR offered proved to be more appealing to students than traditional teaching methods in the form of lectures and slides presentations. Though other third-party VR applications like Short Circuit VR have impressive graphics and more streamlined usability, the results of this work-in-progress study showed that students cared most about course relevancy and customization. These two qualities were unique to VR content custom-developed by the student developers/researchers.

The future of this research will start with improvement being made to MetavoltVR in accordance with feedback received from the beta tests, especially the focus group reflections. Once these changes are applied, the application, i.e., MetavoltVR 3.0 will undergo another round of testing, but this time in the ECE90 classroom. The integration will start with only covering a few course concepts and eventually be worked up to covering the entire course. The application will also be expanded and tested in relevant ECE labs, with the objective of assessing whether this type of VR content is helpful as a supplement to application-based higher-order learning in addition to theory-based cognitive learning.

## 6. Acknowledgement

This material is based upon work supported by the National Science Foundation under DUE/IUSE-HSI Award # 2126723. We would also like to thank the undergraduate electrical and computer engineering students that volunteered their time to test MetavoltVR and provide us with their valuable feedback.

**References**


[1] J. Pomerantz, "Learning in Three Dimensions: Report on the EDUCAUSE/HP Campus of the Future Project," in "ECAR research report," EDUCAUSE, Louisville, CO, August 2018 2018.

[2] J. Pomerantz, "XR for Teaching and Learning: Year 2 of the EDUCAUSE/HP Campus of the Future Project," in "ECAR research report," EDUCAUSE, Louisville, CO, 2019.

[3] J. Pomerantz, "Extending XR across Campus: Year 2 of the EDUCAUSE/HP Campus of the Future Project," in "ECAR research report," EDUCAUSE, Louisville, CO, 2020.

[4] Y. M. Tang, K. M. Au, H. C. W. Lau, G. T. S. Ho, and C. H. Wu, "Evaluating the effectiveness of learning design with mixed reality (MR) in higher education," *Virtual Reality*, vol. 24, no. 4, pp. 797-807, 2020, doi: 10.1007/s10055-020-00427-9.

[5] N. Vézina, C. IsaBelle, H. Fournier, A. Dufresne, and J.-J. Doucet, "3D Virtual Reality: Motivation, sense of belonging and perseverance," in *EdMedia+ Innovate Learning*, 2004: Association for the Advancement of Computing in Education (AACE), pp. 1677-1682.

[6] S. Cheryan, A. N. Meltzoff, and S. Kim, "Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes," *Computers & Education*, vol. 57, no. 2, pp. 1825-1835, 2011, doi: 10.1016/j.compedu.2011.02.004.

[7] T. C. Peck, M. Doan, K. A. Bourne, and J. J. Good, "The effect of gender body-swap illusions on working memory and stereotype threat," *IEEE transactions on visualization and computer graphics*, vol. 24, no. 4, pp. 1604-1612, 2018.

[8] C. R. Starr, B. R. Anderson, and K. A. Green, "“I’m a Computer Scientist!”: Virtual Reality Experience Influences Stereotype Threat and STEM Motivation Among Undergraduate Women," *Journal of Science Education and Technology*, vol. 28, no. 5, pp. 493-507, 2019, doi: 10.1007/s10956-019-09781-z.

[9] N. Yannier, S. E. Hudson, and K. R. Koedinger, "Active Learning is About More Than Hands-On: A Mixed-Reality AI System to Support STEM Education," *International Journal of Artificial Intelligence in Education*, vol. 30, no. 1, pp. 74-96, 2020, doi: 10.1007/s40593-020-00194-3.

[10] A. F. Di Natale, C. Repetto, G. Riva, and D. Villani, "Immersive virtual reality in K-12 and higher education: A 10-year systematic review of empirical research," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2006-2033, 2020, doi: 10.1111/bjet.13030.

[11] D. Parsons and K. MacCallum, "Current Perspectives on Augmented Reality in Medical Education: Applications, Affordances and Limitations," *Adv Med Educ Pract*, vol. 12, pp. 77-91, 2021, doi: 10.2147/AMEP.S249891.

[12] W. Wu *et al.*, "Barriers and pathways to use extended reality in stem classrooms: perspectives of key stakeholders," presented at the 2023 European Conference on Computing in Construction and the 40th International CIB W78 Conference, Crete, Greece, 2023, 305. [Online]. Available: https://ec-3.org/publications/conference/paper/?id=EC32023_305.

[13] A.-M. Iversen, A. S. Pedersen, L. Krogh, and A. A. Jensen, "Learning, Leading, and Letting Go of Control," *SAGE Open*, vol. 5, no. 4, 2015, doi: 10.1177/2158244015608423.

[14] K. MacCallum, "The integration of extended reality for student-developed games to support cross-curricular learning," *Frontiers in Virtual Reality*, vol. 3, 2022, doi: 10.3389/frvir.2022.888689.
[15] K. Ananiadou and M. Claro, "21st Century Skills and Competences for New Millennium Learners in OECD Countries," in *OECD Education Working Papers*. Paris: OECD Publishing, 2009, ch. No. 41.
[16] T. Anderson and J. Shattuck, "Design-Based Research," *Educational Researcher*, vol. 41, no. 1, pp. 16-25, 2012, doi: 10.3102/0013189x11428813.
[17] S. Barab and K. Squire, "Design-Based Research: Putting a Stake in the Ground," *Journal of the Learning Sciences*, vol. 13, no. 1, pp. 1-14, 2004, doi: 10.1207/s15327809jls1301_1.
[18] J. Chalhoub and S. K. Ayer, "Using Mixed Reality for electrical construction design communication," (in English), *Automat Constr*, vol. 86, pp. 1-10, Feb 2018, doi: 10.1016/j.autcon.2017.10.028.
[19] W. Wu, J. Hartless, A. Tesei, V. Gunji, S. Ayer, and J. London, "Design Assessment in Virtual and Mixed Reality Environments: Comparison of Novices and Experts," *Journal of Construction Engineering and Management*, vol. 145, no. 9, p. 04019049, 2019, doi: 10.1061/(asce)co.1943-7862.0001683.