2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34519

# Collaborative Problem Solving in a Virtual Electrical Circuits Class

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# Collaborative Problem-Solving in a Virtual Electrical Circuits Class


## Abstract

While online teaching and learning during a pandemic has presented some unique challenges, it has also paved the way for some transformative opportunities. Courses that rely on a mathematical and problem-solving based approach have traditionally benefited from collaborative learning. Collaboration in the classroom provides a structure for student-centered peer instruction, while also fostering connections and building relationships. Research supports the positive impact of collaborative learning, especially for students who are disadvantaged and/or less-prepared- a group that is already disproportionately impacted by the pandemic and online learning. The shift to remote learning has forced us to reimagine collaborative problem-solving in the online space.

In this work, we share our observations and student feedback on the use of Zoom breakout rooms, Microsoft Whiteboard, and a graphics tablet to facilitate collaboration using shared-ink in a synchronous online Electrical Circuits II course. Using the combination of asynchronous content, video conferencing rooms, and collaboration tools, we have been able to replicate, as closely as possible, a collaborative problem-solving experience for students. This paper will document the related pedagogical design, virtual classroom implementation, qualitative student feedback, and classroom observations by an evaluation consultant.


## Introduction

The abrupt transition from in-person to remote learning in the midst of the pandemic has disrupted the education landscape worldwide. As educators and students navigate the online learning space, it has become apparent that the learning curve is steepest for courses that typically involve significant hands-on and/or problem-solving components. In this regard, engineering education has been profoundly impacted by the challenges associated with delivering laboratory content and design experiences remotely. In a qualitative survey conducted by the American Society for Engineering Education (ASEE) to help assess the impact of the pandemic on the engineering education community **[1]**, respondents overwhelmingly considered the loss of lab-based, hands-on instruction to be the leading problem faced by engineering educators. Approximately 120 out of 207 responses included the terms “hands-on,” “lab” or “laboratories,” or both, and another 20 mentioned “team,” referring to activities and projects. In comparison, although lecture courses have been impacted to a lesser extent, the development of problem-solving skills using active learning techniques has faced similar challenges.

Decades of pedagogical research that primarily focused on learning activities and best practices in the physical classroom are now being adapted for use in virtual classrooms. It is, however, uncertain if these interventions are impactful to the same extent as originally intended. For example, collaborative learning is associated with benefits in outcomes related to social, psychological, academic, and assessment skills **[2] [3] [4]**. It is shown to contribute towards fostering a supportive environment that involves students actively in the learning process, while also promoting their critical thinking, oral communication, and interpersonal skills. Collaborative learning communities are known to empower culturally diverse students **[5] [6]** and improve retention of minority students **[7]**. However, the body of knowledge surrounding best practices for facilitation of collaborative learning in virtual classrooms is limited.

This paper documents the process of integrating collaborative problem-solving in a virtual Electrical Circuits II course through the use of digital collaboration tools. The method of implementation is presented, followed by a description of evaluation activities conducted by an external consultant. This includes in-class observations, focus group sessions, and a post-course survey.

## Virtual Classroom Implementation

The Electrical Circuits II course offered by the Electrical and Computer Engineering department at Seattle University is a junior-level course that introduces students to AC circuit analysis and the concept of frequency response. The course is typically structured to include lectures, weekly assignments, and three exams. Since this lecture course has a corresponding laboratory offering in the same term, all hands-on experimentation is limited to the lab course.

Due to the virtual nature of the course in Fall 2020, all class sessions were conducted via Zoom. Since problem-solving is an integral part of this course, it was important to find a creative way of engaging students, while also fostering connections. A survey on the technology available to the 29 students enrolled in the course was administered a few weeks before the start of the term. It was found that only 9 students had access to an ink-capable device i.e., a tablet or computer with a touch-enabled screen that could be navigated using a stylus pen. In an effort to provide the remaining 20 students access to a device with similar capabilities, low-cost graphics tablets (~$40 each) were purchased and mailed out to them. As shown in Figure 1, this 2mm thick USB-compatible tablet with an active area of 6X4 inches could transform any desktop or laptop into an ink-capable device.

Course content was carefully organized into 'before class', 'during class', and 'after class' categories. Students were expected to watch pre-recorded lecture videos and complete a quiz before attending synchronous class sessions on Mondays and Fridays. These sessions began with an instructor-led overview of topics covered followed by Zoom breakout sessions where students would work in teams of three of four to collaborate on assigned problems using a shared Microsoft Whiteboard. With all members of a team having access to a shared whiteboard, collaboration was made possible in real-time. Students were expected to engage with each other


Figure 1: XP-PEN StarG640 Digital Graphics Tablet [https://www.xp-pen.com/product/51.html]

in a respectful and inclusive manner as they worked towards understanding the problems and arriving at solutions, collaboratively. These expectations were conveyed by the instructor at the start of the term and frequently reiterated thereafter. Moreover, students taking the co-requisite laboratory course received formal guidelines on creating and maintaining a positive culture while working as a team to understand the engineering design process. Team assignments in the lecture course were changed at the end of every module/chapter to give students the opportunity to interact with as many of their peers as possible. The instructor rotated through breakout rooms to help answer questions and provide prompts to encourage student discourse, when necessary. Breakout rooms were closed five to ten minutes before the end of each session to get together as a class and share observations or misconceptions that were noticed during group work. Wednesday class sessions were used as open office hours to address student queries and they included some instructor-led problem-solving. As with the traditional in-person course, students had weekly or bi-weekly assignments and three exams over the duration of the term.

Examples of topics covered in the course and related problem-solving sessions included sinusoidal analysis of AC circuits, AC power analysis, Laplace Transforms and its applications in circuit analysis, and frequency response-Bode plots, transfer functions, resonant circuits and filters. Each team used a shared whiteboard to paste an image of the assigned problem followed by annotation of the solution using an appropriate problem-solving technique (node-voltage, mesh-current etc.). The ability to paste images on the whiteboard also results in a convenient and efficient way to sketch bode plots on a semi-log graph. With all members of a team having access to the shared whiteboard, it makes it easier to identify errors in equations and computations. Figure 2 presents a screenshot of a shared whiteboard that illustrates the collaborative problem-solving process. It should be noted that the screenshot was captured with the intention of demonstrating the collaborative process and not the accuracy/inaccuracy of the solution.

Using a combination of asynchronous content, video conferencing rooms, and collaboration tools, it was possible for us to replicate, as closely as possible, a collaborative problem-solving experience for students. The underlying goal of this work was to provide students the opportunity to develop their problem-solving strategies as well as their metacognitive awareness, while building a sense of community in an online class that could otherwise feel isolating.

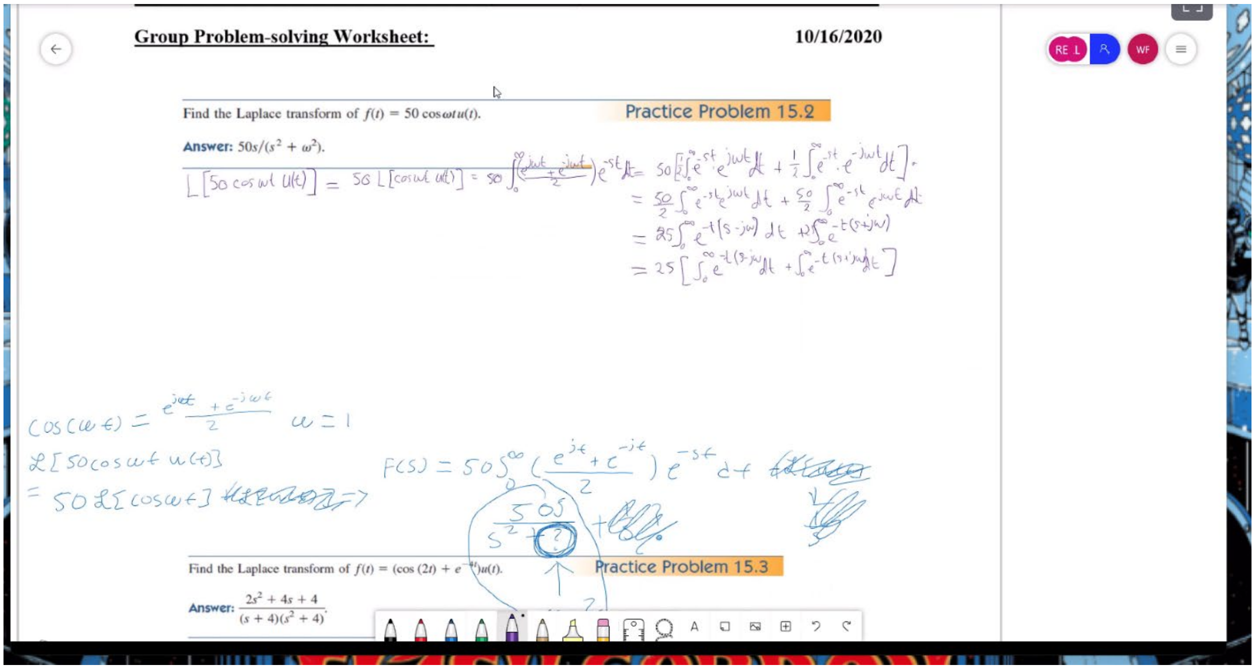



Figure 2: Screenshot of a shared whiteboard that was captured during a problem-solving session

## Virtual Classroom Observations and Evaluation

To gauge the impact of this initiative on student learning and to capture student experience with the collaborative tools, carefully designed evaluation activities were conducted by an external evaluator. Evaluation methods included virtual classroom observations, in-class focus groups, and a post-course survey. Using multiple methods in this way provides for methodological triangulation, where one question is investigated from multiple angles, thereby enhancing the validity of the study **[8] [9] [10] [11]**. By comparing the statements of the students in focus groups with their anonymous survey responses and observations of them interacting in class, it was possible to get a fuller picture of the student experience in the course. In this study, what students shared about the digital tools matched well with how they were participating in the course. Survey and focus group responses were completely anonymous to the instructor and results of the survey were presented in aggregate form.

Virtual classroom observations by the evaluator were conducted during three separate synchronous class sessions, spread out through the duration of the term. Over the course of these sessions, the evaluator observed seven groups interacting for five to ten minutes and observed an additional three groups interacting while conducting focus groups. Of the ten breakout rooms that were observed, every group was using a shared Microsoft Whiteboard, but with varying ink-capable devices. Although all ten groups were working on the assigned problems, only eight of those groups were actively engaged in discussions, while working on the shared whiteboard. Several groups used different colored ink to designate different writers within their groups so that individual contributions were recognized. Of the two groups where active discussion was not going on during the observation, only some students wrote on the whiteboard, while others were silent observers. They may have been working individually but were not engaged in active conversation. Overall, 100 percent of groups observed were using shared whiteboards and 80 percent of groups were actively engaged in discussions.

On the first day of observations, it was noted that groups were still adjusting to the collaborative tools and they experienced some difficulties working with the technology. By the second session, there still some discussions about technology, but the majority of conversations were focused on course content and assigned problems.

Focus group sessions were held on the third day of classroom observations, and eleven students from three different breakout rooms participated in them. Students strongly supported the distribution of tablets to students who needed them. They agreed that it was critical because of the nature of online work and that it was important to provide a level playing field.

> *"It's very important for everyone to be able to be involved, and so if people are you know lacking in that technological capability and there's something that can be fixed – I think it's kind of a responsibility of the institution to provide equal learning opportunities to everyone."*

Several students who had been given tablets felt that they had benefited from them greatly, both inside and outside of class. While most students used their tablets during the collaborative problem-solving sessions, some students also used their tablets for homework and during the lecture portion of class.

> *"I've also been using [my tablet] a lot outside of class. Just really like a scratch paper … And it's nice because I can save them and I don't have to worry about like wasting actual paper and then figuring out like where to put that paper so that's been useful for me. … the ability to copy and paste is infinitely better. It makes it so much easier, especially for certain circuit problems."*

Some students who were given tablets did not use them, citing difficulties with their use. One student stated that they found their computer's trackpad easier to use. Another said that they had a small computer and didn't have room for an additional USB device. And a final student said that they ended up buying a surface laptop with a touch screen because they found the tablet was not serving their needs.

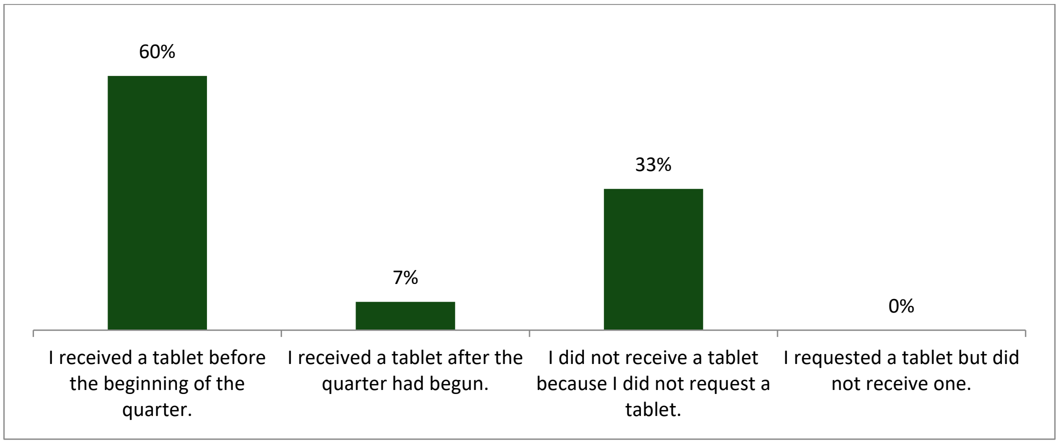
Overall, students found that being able to use inking capability whether with the graphics tablet, a touch-screen laptop, or a computer mouse greatly improved their class experience and their ability to work with other students. Students appreciated the ability to work collaboratively through shared whiteboards. They believed that it contributed to the classroom community and helped them interact with each other. As one student stated, "using whiteboard is a good alternative to being in person."

> *"It's definitely very convenient to have … it's like, as close as we can get to working on an actual whiteboard together. You can see everyone working, and it's all there, all of the writing …, you have a lot more freeform than if you're typing on text on something like OneNote… you can see the different ways everyone works through the problem."*
>
> *"… I felt like everyone kind of contributed in their own way. And anytime you kind of like make a small error it's really easy to see what other students are doing too, and it's easy to correct your errors being able to see what your peers are doing. So it makes sense."*
>
> *"I'd also say [groupwork] was helpful. I guess, getting to know more students. Because otherwise you're just sitting in the lecture and not really talking to each other. So it was a good way for us to communicate together."*
>
> *"It's much slower, writing out your work on the whiteboard, rather than just on a piece of paper."*

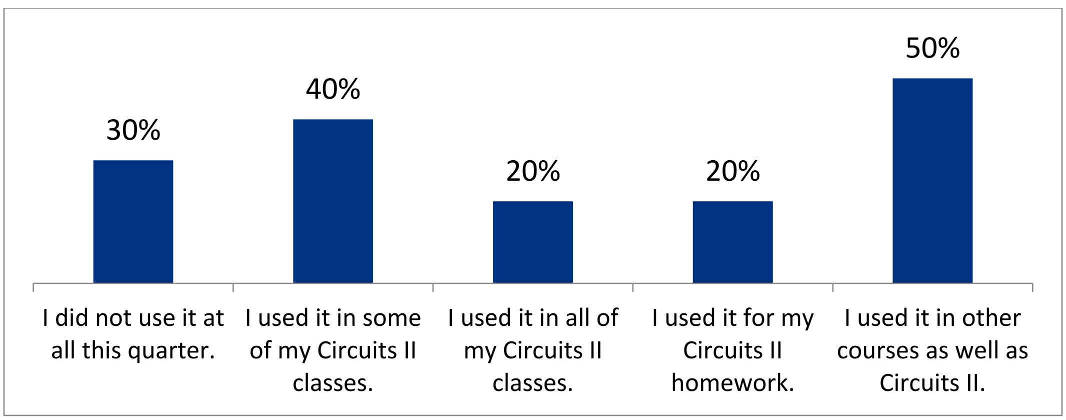
A post-course survey was administered towards the end of the term, with a response rate of 51.72 percent. Of the 15 respondents who provided survey data, 67 percent reported receiving a tablet. Every student who requested a tablet received one, with 90 percent of those requesting a tablet receiving it before the start of class. For those respondents who received a tablet, 70 percent reported using it in their Electrical Circuits II class. Thirty percent of respondents used it as their only device, 10 percent used it with some use of another device, and 20 percent used it equally with another device. The most common devices used with the tablet were a laptop without touch capabilities (two respondents), an iPhone (one respondent), and an iPad (one respondent). For the students who received a tablet but did not report using it in class, two used a laptop with a touchscreen and one used a laptop without touch capabilities. In a focus group, one student reported purchasing a touchscreen laptop after the start of class because of issues she found with the XP-tablet.

Fifty percent of respondents who received a tablet reported using it in other classes in addition to their Circuits II course, and 50 percent of students who received the tablet found it likely that they would use it in future terms. A majority of all respondents reported that using Whiteboard with their classmates was effective (60 percent) and that working with groups helped their learning (60 percent). Fifty-three percent of all respondents reported feeling a strong sense of community in the class. Survey results are illustrated below.

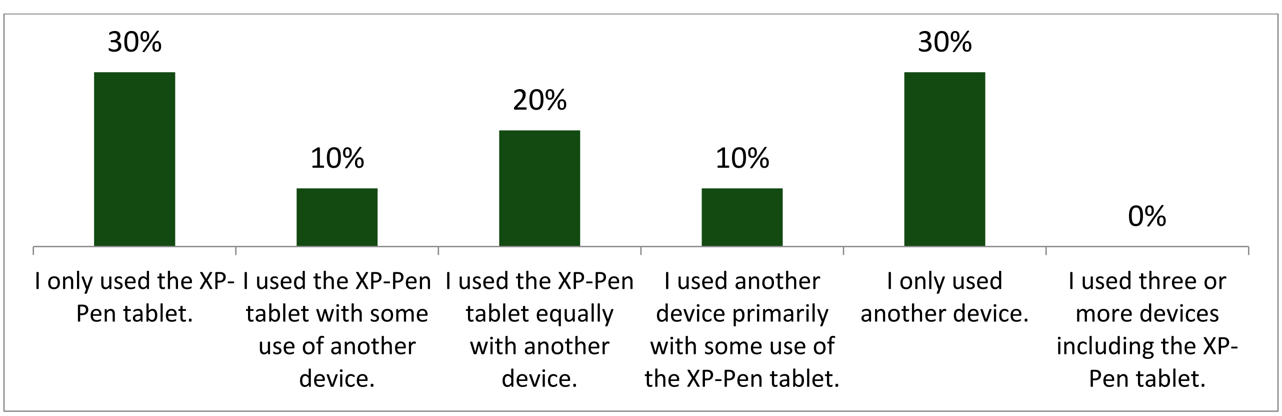
**Did you receive an XP-pen digital graphics tablet at the beginning of the quarter? (n=15)**



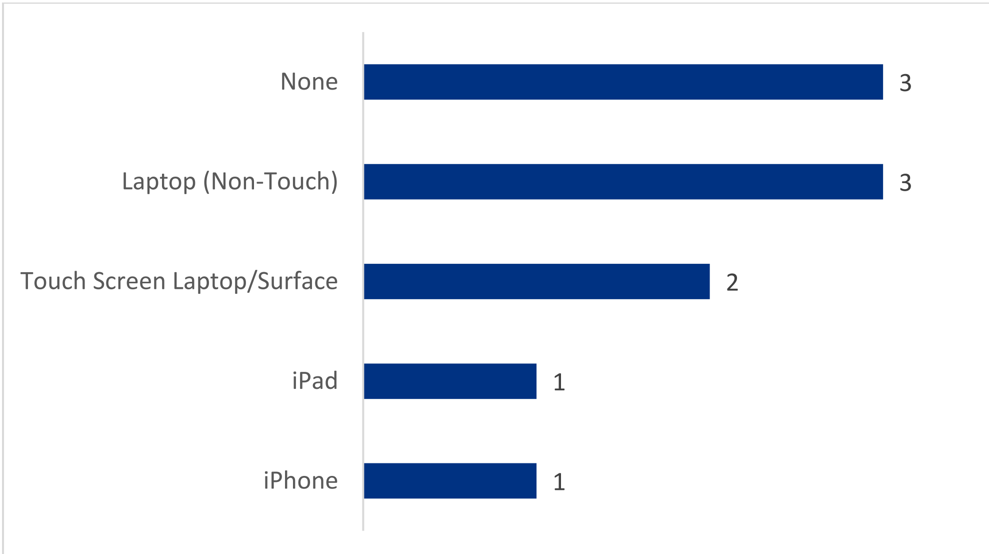

**How often did you use the XP-Pen digital graphics tablet in this course? Please check all that apply. (For those who received a tablet) (n=10)**



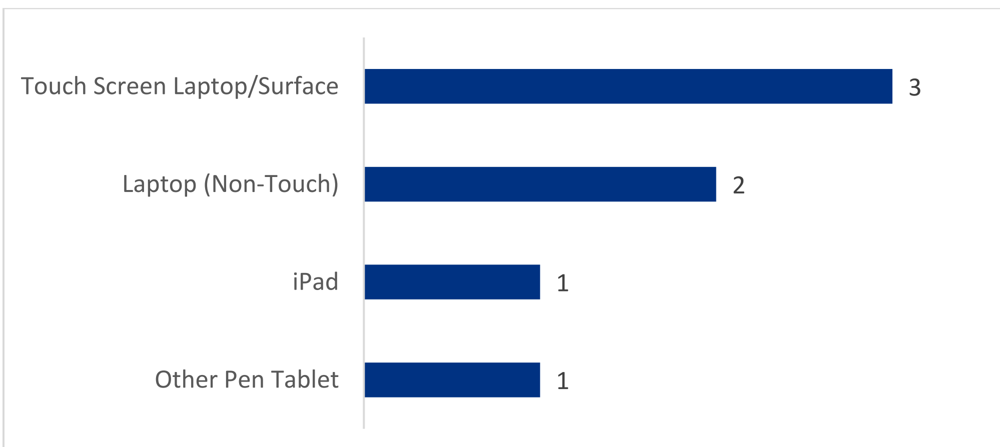

**What device(s) did you use primarily in your Circuits II courses? (For those who received a tablet) (n=10)**



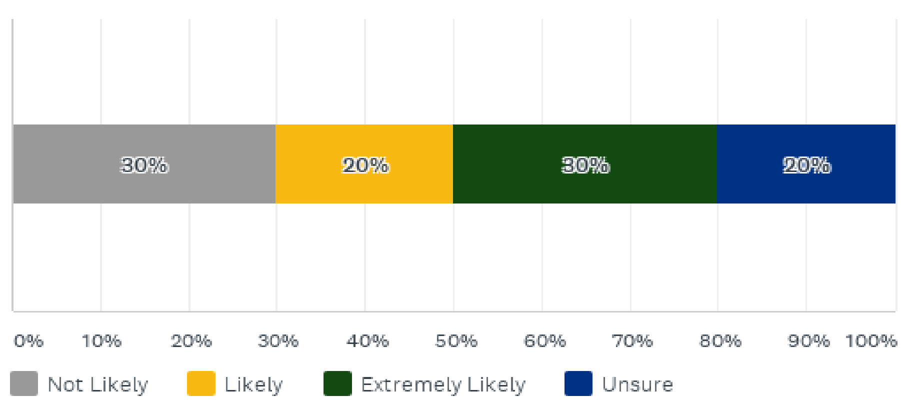
**Other devices used during Circuits II for those who received a tablet (n=10)**



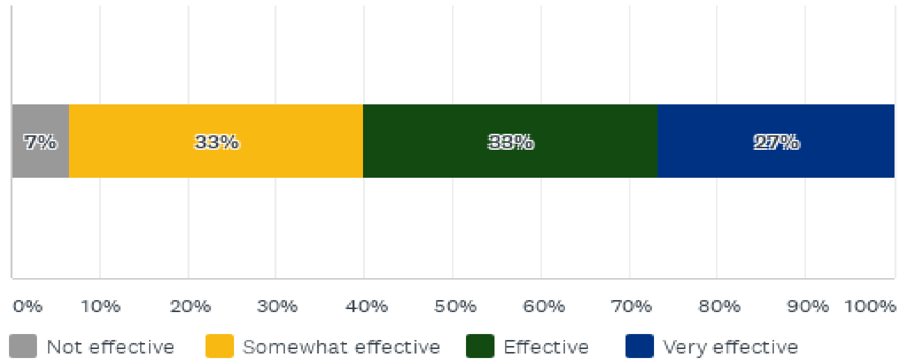

**Devices Used During Circuits II by students who did not request a tablet (n=5)**



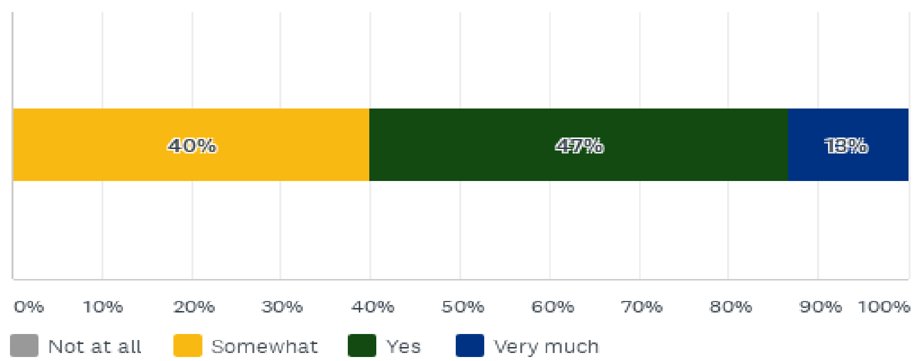

**To what extent do you anticipate using the XP-Pen digital graphics tablet in future courses? (n=10)**



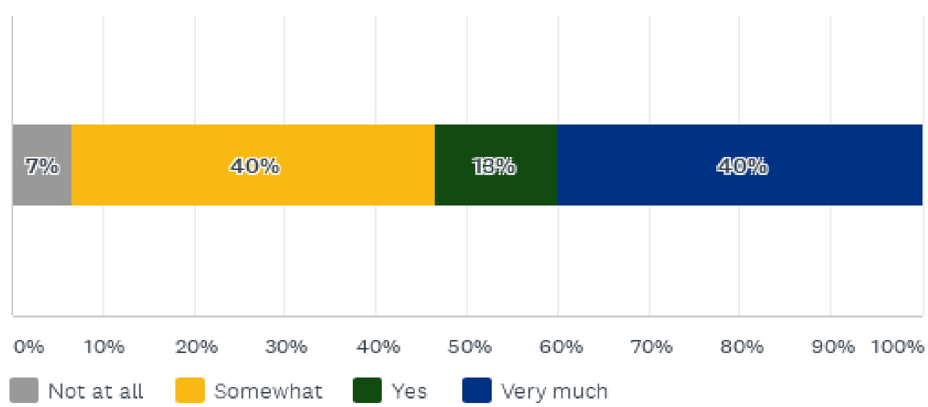
**How effective did you find using Whiteboard with your classmates? (for all respondents) (n=15)**




**Did working in groups with other students help your learning? (for all respondents) (n=15)**




**Did you feel a sense of community in this course? (for all respondents) (n=15)**



## Recommendations for Future Implementations

Based on our observations and student feedback, it is apparent that students appreciated our efforts to reimagine collaboration in the online space. However, this experience has highlighted some shortcomings with the digital tools that were used. While students agreed that the XP-PEN graphics tablet was a vital tool to have, especially for students who might not have another option, they did encounter difficulties with ease of use. If funds allow, a higher quality device could be provided to students. While Microsoft Whiteboard as a collaborative tool was greatly successful, it was also noticed that teams with more than three students faced occasional lagging or freezing of the screen when accessing the shared whiteboard. It is interesting to note that some students found that this tool offered functionalities superior to working in person. Once courses are back in person, using Whiteboard as a tool is something that could be continued, either in homework groups, online office hours, or as a part of in-person group work.

Other possibilities for improvement include a more thoughtful process for creation and rotation of team assignments, a requirement for teams to submit their shared worksheets as part of the course deliverables and assigning participation credits to encourage more active engagement during the collaborative sessions. A special focus on creating community in the classroom, during the initial class sessions, could help students feel at ease in the breakout rooms, thus making the collaborative sessions more interactive.

## Conclusion

In response to the transition from an in-person to virtual class for Electrical Circuits II, an interactive problem-solving approach was implemented using digital tools and collaborative technologies. This approach has shown promise in helping online courses foster a stronger sense of community, while also enhancing student problem solving skills through peer learning. The student experience was captured using multiple methods of evaluation, including virtual classroom observations, focus groups, and a post-course survey.

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