A Mercer XLab Study: How personal instrumentation compares to open-access benchtop equipment as heutagogical tools for improvisational learning

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Shayla Sawyer is a Professor in the Electrical, Computer, and Systems Engineering Department at Rensselaer Polytechnic Institute. Her research explores the interconnection of hybrid materials for high-performance devices. These nano-bio devices are comprised of hybrid inorganic/organic materials, which may include semiconductor metal oxide nanostructures, bacteria, conductive polymers, conductive nanostructures, and bio-chemical solutions. Her overall research goal explores effectively fabricating and characterizing novel materials and sensors with consideration of systems that require sensitivity and/or selectivity to bring quantitative measurements in typically qualitative worlds. The inherent team-based, collaborative focus embedded in her technical research extends to her teaching and learning research. She is the inaugural Director of the Douglas A Mercer '77 Innovation and Exploration Laboratory (Mercer XLab). Dr. Sawyer is a highly regarded teacher for her unorthodox teaching style and Alpha Omega Lab innovation. She has received all of the highest teaching awards at RPI and in the School of Engineering, including the Outstanding Teaching Award for Innovation in Education in 2025. She was selected by students for the 2023 David M. Darrin '40 Counseling Award.

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Abstract

Improvisational engineering incorporates design thinking, student agency, creativity, practice using engineering judgment, and interconnecting core concepts through assessments of fundamental knowledge in hands-on laboratory experiences. This study focuses on how experimental measurement tools, their size, cost, and ease of use, affect the students' path from learning dependence in pedagogy to self-directed learning andragogy and heutagogy. It compares stand-alone benchtop equipment available in the Mercer XLab to personal instrumentation, such as the Analog Discovery Board and ADALM2000 (M2K) board. Personal instrumentation integrates multiple benchtop instruments into a small, portable device connected by USB to a laptop. The work is facilitated by collaboration between the Science and Technology Studies (STS) department in the School of Humanities, Arts, and Social Science and the Electrical, Computer, and Systems (ECSE) Engineering department in the School of Engineering. PhD students from each department expanded their research interests to include this exploration toward improvisational engineering education. The STS PhD student's PhD thesis, "Producing Music, Producing Culture," is a direct analogy to this study. His research treats the Music Production Center (MPC) as personal instrumentation for music and recording equipment in traditional music studio as benchtop equipment in the Mercer XLab. Thus, the foundation of his thesis, considering "technology of stylization" as a technical framework and methodology for spontaneous creative practices, is analyzed for heutagogical study in the hands-on, ECSE lab context. This study compares the confidence and competence of students using personal instrumentation with those using benchtop equipment in the Mercer XLab for the second-year Electric Circuits (ECSE-2010) course during the Spring 2025 semester. Furthermore, a comparison is made between students' preferences for Alpha (Traditional) labs and Omega (Design) Labs regarding both benchtop and personal instrumentation usage. Omega Labs, an example of improvisational engineering, requires risk, engineering judgment, iteration, and creativity and thus reflect the effect of factors such as instrumentation availability, personnel support, ease of use, measurement limitation, and portability on creative risk. Finally, qualitative comments are summarized for students that participated in interviews throughout the Spring 2025 semester.

Introduction

The Douglas A. Mercer '77 Innovation and Exploration Laboratory, known as the Mercer XLab, is an educational "third place" that provides open access to electronic instrumentation, electronic parts (both traditional and cutting-edge), student-led technical support, technician support, a tenured, research-active engineering faculty member in leadership, and curated educational modules to foster a growing learning ecosystem. It provides a dedicated, open-access space to build innovations, find collaborations, share technical tools, and aggregate results from the learning community to multiply the impact of innovators. The Mercer XLab opened its doors in September 2024 and is rapidly growing into a prototype of the new wave of engineering education, one that is built on diversity of thought and the fluid exploration of learning approaches from pedagogy (dependent learning) to andragogy (independent, self-directed learning), toward its final stage, heutagogy (interdependent, self-directed learning). Progression through learning approaches requires dedicated time and a variety of tools, along with supporting resources, which are readily available to students. Traditional classroom learning usually involves a fixed structure, with specific tools and procedures chosen in advance for students. In contrast, improvisational learning allows learners to use any available instrument at any time, encouraging playful exploration and creative connections that are tailored to each individual while proving specific course concepts. In this way, the framework and methodology of technology of stylization in the engineering context is analogous to musical improvisation.

Since the late 1990s, Rensselaer Polytechnic Institute implemented Personal Instrumentation in its courses [1-3]. Following their introduction, the Analog Discovery Board, ADALM2000 (M2K), and ADALM (M1K) have been integrated into foundational courses throughout the curriculum. These USB-powered portable devices incorporate ~$50,000 of benchtop equipment for ~$250.00, turning any PC into a versatile electronic measurement setup. Personal instrumentation combines oscilloscopes, waveform generators, logic analyzers, and power supplies using software like WaveForms, Scopy, or Alice. During the COVID pandemic, the dependence on personal instrumentation deepened and lab activities were designed to become instrumentation agnostic. This was facilitated by the Proof of Skill assignment required in the first few weeks of the semester in first year and second-year fundamental courses, Introduction to ECSE (ECSE-1010) and Electric Circuits (ECSE-2010) respectively.

Background

The opening of the Mercer XLab is aligned with the distribution of improvisational engineering practices throughout the curriculum by incorporating Alpha and Omega Labs into one core course in every year of matriculation. The Alpha and Omega Lab Continuum originated in the second-year course, Electric Circuits. Students are given autonomy to choose their lab type. The first is the Alpha (Traditional) labs, which are procedural and step-by-step in nature. All courses already have a traditional lab. The instructor provides these students with circuits to analyze to prove a concept. They conduct a small design experiment at the end of each lab. The second is the Omega (Design) labs. The Omega Labs were added to reinforce Design Practice and Design Thinking. These labs start with the class theme from an ideation on the first day or an explorative direction decided by the group from a menu of options. It requires proving fundamental concepts with a circuit designed by the students, instead of the instructor, to meet a societal need. It calls upon their creativity while requiring a clear project plan and an acute understanding of course concepts and how they apply to their ideas. The level of abstraction is a significant challenge for students, engaging them in new ways. Omega Labs is an example of improvisational engineering embedded within the curriculum, but it emphasizes constraint to prove course concepts with their designs using the theory taught in the course. The distribution of Alpha and Omega Labs as Design Practice was the experimental foundation for ABET accreditation data collection during Fall 2024 and Spring 2025.

Table 1: ECE Curriculum Experiment for Fall 2024 and Spring 2025

Omega Lab Design Distribution (Year)	**Electrical Engineering**	**Computer Systems Engineering**
First Year Course(s)	ECSE-1010 Introduction to ECSE	ECSE-1010 Introduction to ECSE ECSE-2610 COCO
Second Year Course(S)	ECSE-2010 Electric Circuits	ECSE-2010 Electric Circuits
Third Year Course(s)	ECSE-2050 Introduction to Electronics	ECSE-2660 Computer Architecture, Networks, and Operating Systems

This study uses quantitative data from Electric Circuits (ECSE-2010). Qualitative data includes survey responses from students in the five courses listed in Table 1.

Methods and Tools

Proof of Skills – Assignment and Essential Skills Survey

Proof of Skills in Electric Circuits is a pre-laboratory assessment that is an individual evaluation of 1) Circuit Simulation 2) Experimental Measurements and Personal Instrumentation 3) Analytical Calculations with Personal Calculator and MATLAB or equivalent 4) Community, Communication, Asking for Help, Helping Others and Answering for Yourself "Is this right?". The course focuses entirely on this activity during the scheduled lab session for 2-3 weeks in a collaborative environment. Students sit in a common section in the room depending on the skillset they are working on. Teaching assistants are assigned to help each category, and they are encouraged to help each other during this time. All students are required to submit their own work to Gradescope, an online grading and submission system, without duplication of another,

Proof of Skills Learning Objectives	**Proof of Skills Day 1**	**Proof of Skills Day 2**	**Proof of Skills Day 3**	**Proof of Skills Day 4**	**Course Competency Check: Must complete AT LEAST the ESSENTIAL SKILLS (in red) by September 17th (to be graded by the day before drop deadline).** ***After essential skills are completed, you may improve your scores until the end of the semester.***
Circuit Simulation (LTSpice or equivalent)					
I can use operation point **dc analysis** to find voltages across a resistive circuit (***Must be two or more resistors***, *hint: to do something useful to you, try to simulate a homework or class problem!)*	Attempted? Graded Score /5	Attempted? Graded Score /5	Attempted? Graded Score /5	Attempted? Graded Score /5	
I can use **AC analysis** to find the frequency response of an RC or RL filter (*hint: find a filter with or without an op amp, we'll understand how this works later!*)	Attempted? Graded Score /5	Attempted? Graded Score /5	Attempted? Graded Score /5	Attempted? Graded Score /5	
Each of the Circuit Simulation Objectives above should reflect the following goals:					
1. I can **change my schematic and plot background to white** and cut and paste on an external document 2. I can **change the line thickness and color** of my schematic and simulation output 3. I **can label the simulation output clearly with the circuit schematic component names** 4. I can intentionally show the most relevant part of a simulation by **changing the simulation output window**					

Figure 1: Proof of Skills handout example showing a portion of the Circuit Simulation skillset in the Proof of Skills assessment. Essential Skills (in red) are required before the official Alpha or Omega Labs start. Students are marked "proficient" when all formatting standards and the documentation of the correctly performed skill are completed for a total of five points for each skill.

however. Proof of Skills offers a few significant structural advantages including: 1) An ability to ensure students new the learning culture (transfers) or new to the discipline start labs with the same competence level of classmates 2) An ability to review or deepen skills from a previous semester 3) An ability to ensure TAs have a template to learn skills relevant to the course 4) An ability to run labs agnostic to instrumentation and simulation tool choice thus any student can use any tool available as long as the can achieve the skill. Experimental Measurements and Personal Instrumentation in Proof of Skills along with the survey given after the first 3 weeks of the course is the primary data for this study. These data measure confidence and competence with the students' chosen instrumentation. The sample size for the Proof of Skills confidence survey is N=95 students. Students using the Mercer XLab benchtop equipment represent 17% of the course (16 students), while students using personal instrumentation represent 83% of the course (79 students).

Students are provided with a crowd-sourced, student-edited common document with how-to comments, videos, and associated documents for each skill. The How-to document is continuously updated every semester by Electric Circuits students. It is a skill in the Community, Communication, Asking for Help, Helping Others and Answering for yourself "Is this right?' to "add new information, add a comment or make a correction to the Electric Circuits Skills documentation in a meaningful way for future semesters." Students are also provided with Best Examples of former submissions for each skill with instructor comments on formatting and approach. A formal template is not given, nor a specific circuit. This is to support the level of abstraction needed for their future labs in which they repeatedly prove a concept for their specific circuit in their experimental design rather than follow a template. Their written communication skills are guided but then evaluated for their correctness and readability. Every individual student must include their unique schematics, pictures of their setup, well-formatted results that are easy to read, and written descriptions. To prove their skills, any circuit can be used that meet the basic requirements thus, students are encouraged to look ahead in their homework and lab assignments to prove their skill on any circuit useful to them in the future. The Standards Based Assessment (SBA) method is as an assessment for every skill that measures students against a set of well-defined learning standards rather than by comparison to other students. Specific learning outcomes are communicated to students at the introduction of the assignment as a set of "I can…" statements. The grading rubric reflects the same "I can…" statement and is a binary choice for graders. The grader simply determines whether the student demonstrated the content in the statement or did not.

Experimental Measurement and Instrumentation Skillset List
(for M1K board, Analog Discovery 2 Board, M2K board, benchtop instruments, or equivalent)

1. *Essential Skill: I can use my instrumentation or instrumentation board's function generator to create a DC, sinusoid, and pulsed signal and measure with its oscilloscope directly (hint: no circuit necessary but need external wires!)*

2. I can build a resistive circuit and measure dc voltage across ONE resistor using a dc input source and vary dc voltage at least 3 times (-5,+5 and any voltage in between) (Must be two or more resistors, hint: to do something useful to you, try to simulate a homework or class problem!)

3. I can build a resistive circuit and measure the dc current through ONE resistor using a dc source (OR find another way if needed depending on board!) (Must be two or more resistors, hint: to do something useful to you, try to simulate a homework or class problem!)

4. *Essential Skill: I can build a resistive circuit and measure voltage across ONE resistor using a sinusoidal input source (Must be two or more resistors, hint: try to make a sinusoidal source with amplitude 0 to 5V centered at 2.5 V and another from -5 to +5V centered at 0 then document whether your board can accomplish both or only one of these)*

5. I can use my cursor function to show specific voltage and time points.

6. *Essential Skill: I can provide power and measure the output of a working operational amplifier circuit.*

Each skill is submitted with a set of formatting standards shown in Figure 2, essential for technical documentation practice. In addition, formatting standards assists graders. Students learn the importance of considering the reader to convey their work with clarity.

Each of the Experimental Measurements and Instrumentation Objectives above should reflect the following goals:

1. I can use consistent **color coding of wires when I build circuits on my breadboard** to aid in troubleshooting.
2. I can "zoom in" to an oscilloscope output by **changing the time scale (x-axis)** to show important parameters (for example, a sinusoid with 25 cycles would be easier to see if only 3-5 cycles were shown instead!) when needed.
3. I can "zoom in" to an oscilloscope output by **changing the voltage scale (y-axis)** to show important parameters (for example, a sinusoid with 500mV amplitude would be difficult to see with 5V/div…) when needed.
4. I can ***change the THICKNESS*** of my trace lines for easy viewing.
5. I **can change the background color of my oscilloscope output to white** and paste in an external document for easy viewing.
6. I **can label the measurement output clearly** with the circuit schematic component names.

Figure 2: Formatting standards for every skill in the Experimental Measurement and Instrumentation Skillset List. Students are marked "proficient" when all formatting standards and the documentation of the correctly performed skill are completed for a total of 7 points for each skill.

Essential skills must be sufficiently achieved (>80% of essential skill point total) before labs official start 2-3 weeks from the beginning of the semester. At the end of the essential skills deadline, before the labs begin, a Proof of Skills CHECK-IN assignment requests a 1-minute reflection video and leads to a survey "about confidence in your Skills and your choice of Alpha/Omega Labs". The data before and after Proof of Skills are used as a measure of confidence in this study. The survey also asks for more details about the students' reason for choosing Alpha or Omega Labs. The survey choices are identical.

If Essential Skills are not completed, an early warning is sent to the student and student academic advisor. In addition, an individual email from the instructor is sent requiring a completion plan in return that may include instructor office hours, teaching assistant open hours, or Mercer XLab student worker appointments with estimated time of completion. If the plan is not sent, the students are prohibited from starting the lab with a lab team, thus they must work alone for the first lab or milestone and are encouraged to drop the course. The intent is to inundate all students with support resources while raising the expectation of competency for every student, creating a more equitable opportunity for success in the team-based Alpha and Omega Labs. Equity requires clear consequences for not meeting the standard paired with flexible and easy access human, digital, and physical resources.

After the pre-lab Essential Skills are evaluated, students move on to Alpha or Omega Labs and begin their Proof of Concepts. Every individual student is encouraged to continue to improve their Proof of Skills submissions until the end of the semester toward 100% achievement of all skills. For the rest of the semester during labs, every lab group must submit Proof of Concepts which includes analytical calculations, simulations, experimental measurement, and conclusions that reflect engineering judgment ("Is this right?"). Though not a part of this study, the distribution of Alpha and Omega Labs as Design Practice (including Proof of Concepts) was the experimental foundation for ABET accreditation data collection during Fall 2024 and Spring 2025. The work became a central part of the Self-Study Report.

Interviews and Study Surveys

In-person interviews were conducted by a PhD student from the STS department. This graduate student was not involved in grading or instructing any course involved in this study. The STS PhD Student was paired with an ECSE PhD student to help translate domain specific knowledge. To gather more data, a survey was sent to students with the same prompt questions. A total of 25 students participated in additional interviews and identical written surveys as an alternative.

Experimental Results

Proof of Skills – Experimental Measurement Competence by Instrumentation Choice

Experimental measurement competence is determined by the Proof of Skill Experimental Measurement and Instrumentation Skillset List. A maximum of 42 points is available. Three essential skills in this skillset must be achieved before starting labs.

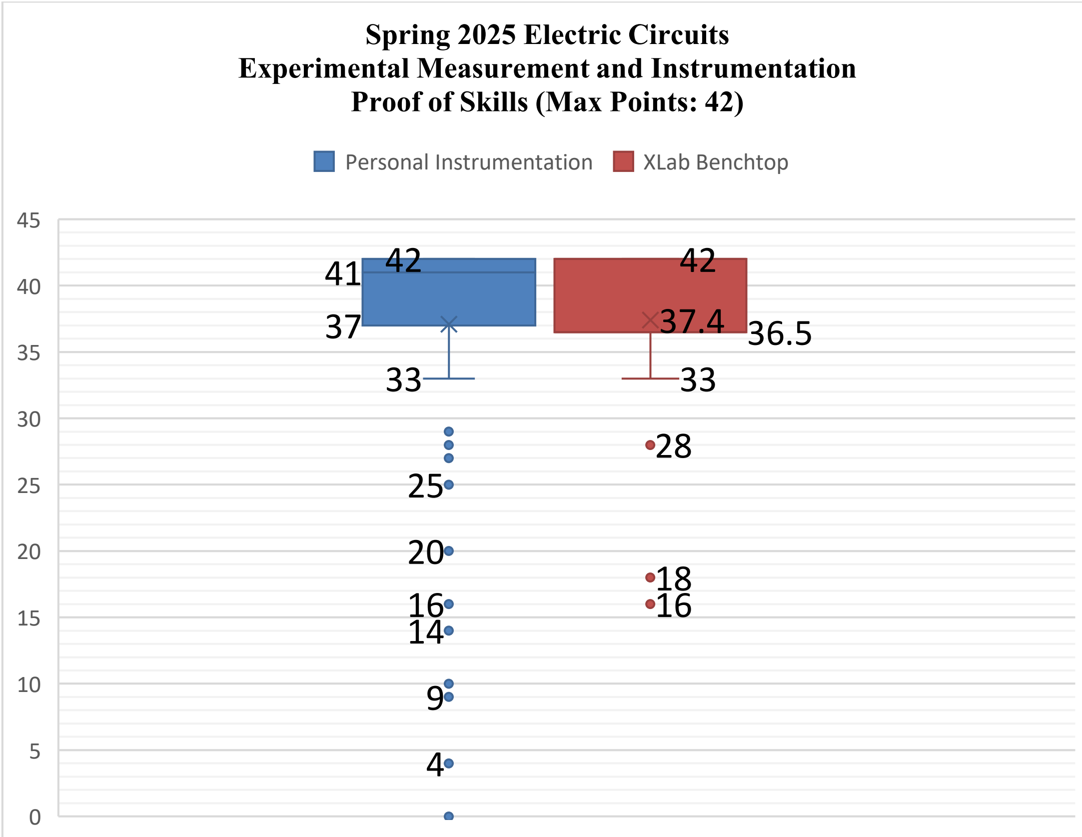


Figure 3: Experimental Measurement and Instrumentation Proof of Skills scores. The maximum score is 42 pts. Personal Instrumentation median score is 41, with an average score of 37. Mercer XLab Benchtop median score is 41 with an average score of 37.4.

The median score for Personal Instrumentation is 41 out of 42, reflecting the number of students with nearly perfect competence. The median score for Mercer XLab Benchtop is 42 out of 42 reflecting the high number of students with perfect competence. The outliers shift the average down in both cases to ~37 out of 42 pts. Both instrumentation choices reflect a high level of competency in the Experimental Measurement and Instrumentation skillset.

Confidence is measured with a before and after Proof of Skills survey when the Essential Skills must be fully completed between 2-3 weeks from the beginning of the course. This is before the official Alpha and Omega Labs begin and before lab teams are formed. The Likert scale is designed to intentionally with seven rather than five options forcing every student to decide if they feel confident or uncertain rather than have an option directly in the middle feeling neither confident nor uncertain. The options include “0 – Never attempted before this class”, “1 – Very uncertain”, “2 – Moderately uncertain”, “3 – A little uncertain “, 4 – A little confident”, “5 -Moderately confident”, and “6 – High confidence “. The combination of Moderate-High confidence is compared to all other options between instrument types. In addition, the number of students deciding they have High confidence after Proof of Skills is compared between instrument types.

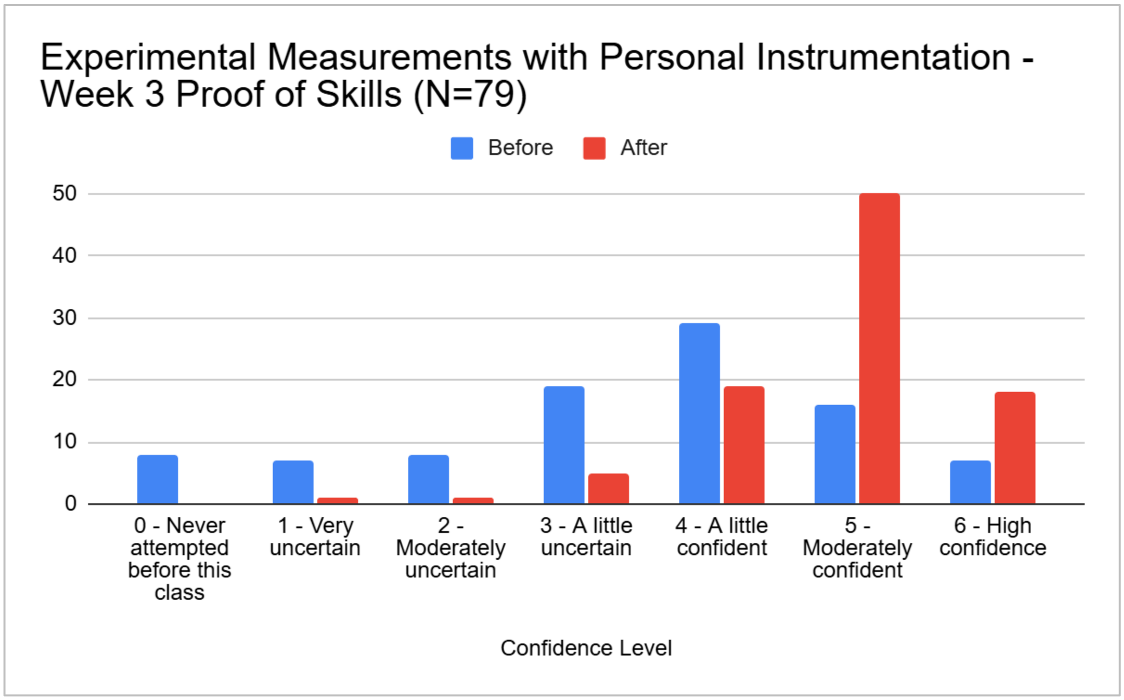


Figure 4: Personal Instrumentation users show 22.8% with High Confidence and 63.3 % with Moderate Confidence. The combined percentage of Moderate-High Confidence is 86.1% for N=79 students out of 95 total students who completed the survey.

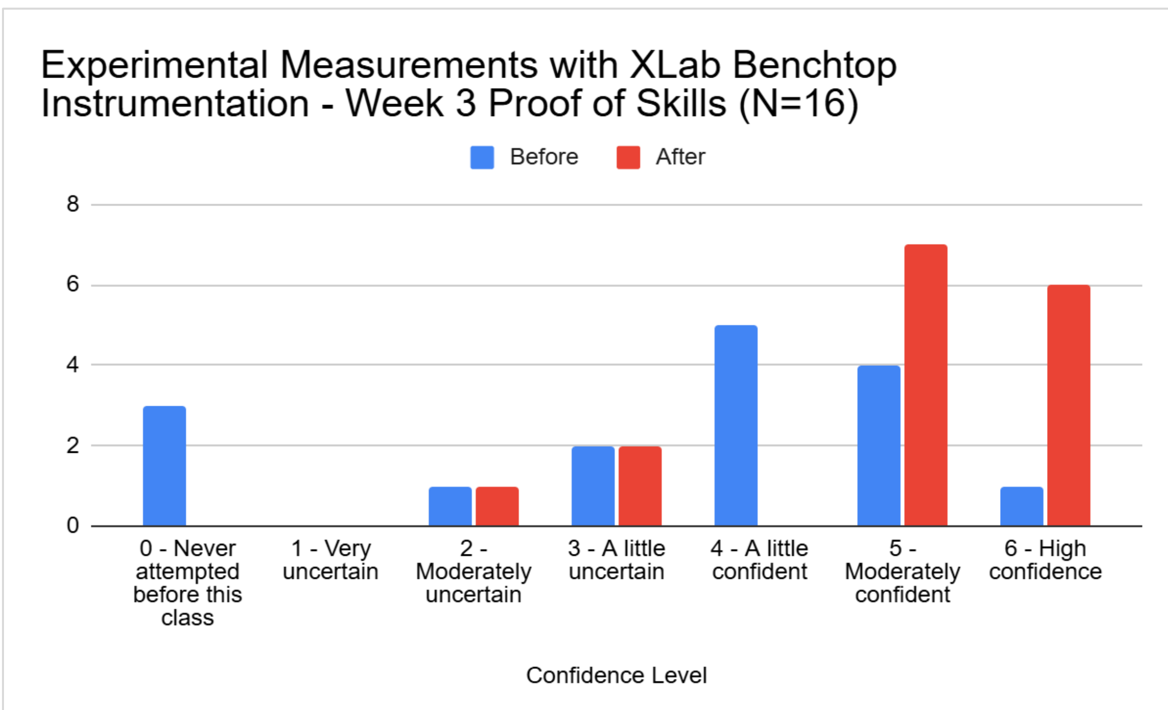
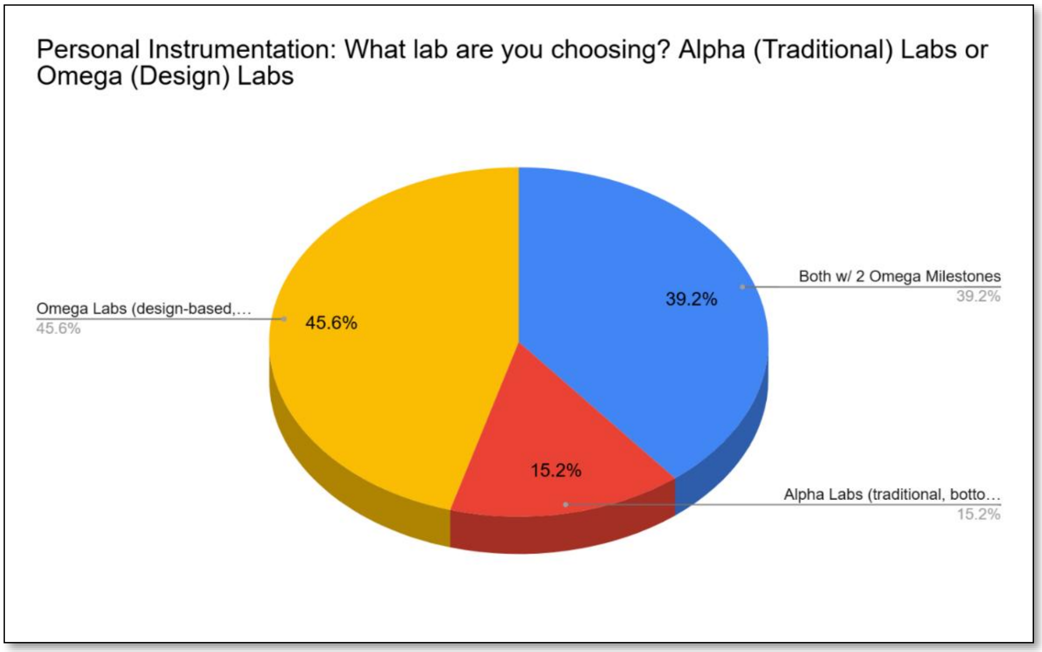


Figure 5: Mercer XLab Benchtop users show 37.5% High Confidence and 43.8% Moderate Confidence with a combined Moderate-High Confidence of 81.3% for N=16 students out of 95 total students who completed the survey.

Personal Instrumentation users conveyed a higher Moderate-High Confidence percentage at 86.1% compared to Mercer XLab benchtop users at 81.3%. However, students conveying High Confidence was higher for Mercer XLab Benchtop students at 34.5% compared to Personal Instrumentation students with 22.8%. When choosing the lab type, 15.2% of those using Personal Instrumentation chose the Alpha (Traditional) Lab which requires less risk with circuit examples provided by the instructor to prove a course concept. All students that used the Mercer XLab benchtop equipment participated in the Omega Labs.



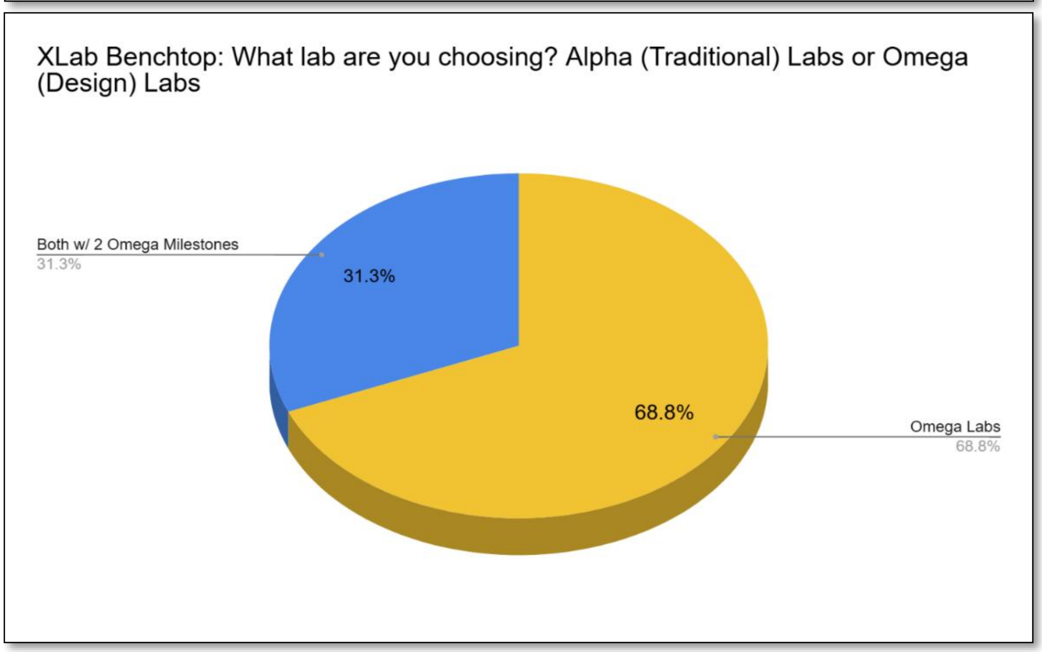


Figure 6: The students' choice between Omega (Design) Labs for all three milestones, Omega (Design) Labs for two out of three milestone and Alpha (Traditional) Labs for Top: Students using Personal Instrumentation, Bottom: Students using Mercer XLab Benchtop Instrumentation. All students using the Mercer XLab Benchtop Instrumentation participated in Omega (Design) Labs for at least two milestones throughout the semester. Only students with personal instrumentation participated in Alpha (Traditional) Labs (15.2%).

Student Agency Reflection on Motivations – Choosing Omega (Design) Labs or Alpha (Traditional) Labs (N=472)

In the same Proof of Skills Confidence Survey, students are asked to disclose their top three reasons for choosing their lab type. "What influenced your decision for Omega Lab? Choose, at most, your top three. (Please mark "I did not choose Omega Labs" if you ***do not*** intend to do at least one Omega Lab)" and "What influenced your decision for Alpha Lab? Choose, at most, your top three. (Please mark "I did not choose Alpha Labs" if you ***do not*** intend to do at least one Alpha Lab)." The survey answers were not easily disaggregated by semester thus the data reflects a larger sample size from 2023-2025 semesters (N=472). All students were provided with the same choices shown below and were required to pick three from the following list:

- I am highly motivated by my perceived challenge/risk level of this lab.
- I don't like risks I want to know EXACTLY every step to learn.
- I'm a top-down thinker...big picture first, small details after
- I'm a bottom-up thinker...small details first, big picture after
- Highly influenced by my lab partner(s) (I wanted to do one, but they wanted to do the other)
- I am not confident in my basic skills yet.
- I am confident in my basic skills.
- My overall course load this semester.
- I believe the final exam is the best way to demonstrate my mastery of knowledge in this course.
- Getting out of the final since I do not believe it is the best way to demonstrate mastery of knowledge in this course.
- I heard about my lab choice as the BEST choice for me from other students who took the class before
- I want to build my resume/portfolio for future employers (deep experience)
- I believe this lab will be better for my GPA (grade driven)

Top 4 reasons for Omega (Design) Lab (N=472 across multiple semesters)

1. I want to build my resume/portfolio for future employers (deep experience) (48.7%)
2. Getting out of the final since I don't believe it the best way to demonstrate my mastery of this course (48.3%)
3. I am highly motivated by my perceived challenge/risk level of this lab (31.8%)
4. **I am confident in my basic skillset (28%)**

   ***The choice "I am not confident in my basic skills yet" was second to last at 11th place (2.1%). Only outperforming "I don't like to take risks…" by 0.3% (1.7%) for Omega Labs.**

Omega Lab choices reflect an ambitious metacognitive position with an emphasis on future employment, alternative mastery demonstration, challenge/risk acceptance, and skill confidence.

Top 4 reasons for Alpha Lab choice (N=472 across multiple semesters)

1. My overall course load this semester (33%)
2. I don't like risks; I want to know EXACTLY every step to learn (21.4%)
3. I believe this lab will be better for my GPA (grade driven)
4. **I am not confident in my basic skills yet (14.2%)**

***The choice "I am confident in my basic skillset" (9.3%) is 6th for Alpha Labs.**

Alpha Lab choices reflect a cautious metacognitive position with an emphasis on courseload during the semester, resistance to risk, GPA improvement, and recognition of a need to improve skills.

Reflections on how the Mercer XLab was used by all students.

In the final course survey, the following questions was asked with a list of choices, including "other": "Did you ever use the Mercer XLab? Is so, in what way?"

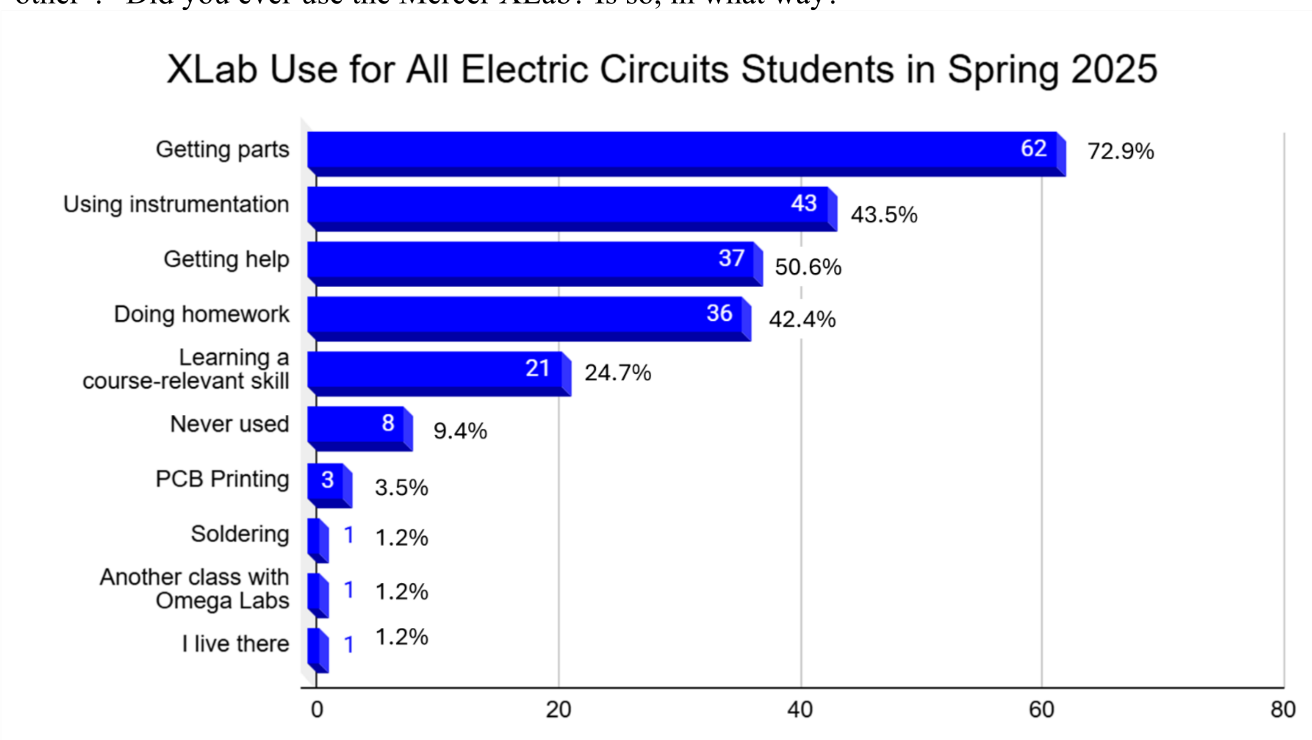


Figure 7: Mercer XLab uses by Electric Circuits Students in Spring 2025. Almost every student in the course used the resources in the Mercer XLab (90.6%) reflecting their usefulness as an easy access, communal learning space, rather than an exclusive makerspace with specialized tools for only highly trained users, as it was designed to be.

The Mercer XLab was used by 90.6% of the Spring 2025 Electric Circuits class for reasons beyond instrumentation. Many students used the Mercer XLab storefront for parts, went to student workers or technical for help, completed homework assignments, or learned an additional course-relevant skill. The organization of the lab, therefore, reflects a communal, easy access, learning space embedded within a makerspace-like environment but without the exclusion often found in spaces with specialized tools that require highly trained workers.

Qualitative Interview and Survey Results
One-on-one interviews were conducted by the external STS PhD student conducting research. In addition, a survey was conducted by the ECSE PhD student and external STS PhD student and provided every course with Omega Labs. The number of students that responded in the interview or survey is (N=25).

General combined comments from both Mercer XLab Benchtop and Personal Instrumentation users:

- Students reflected learning well when using any instrumentation.
- Students were overwhelmingly hands-on and experiential learners, a few were visual, and one learned best through reading.
- Students enjoyed working in teams.
- Mercer XLab Benchtop and Personal Instrumentation users both saw communities form around their instrumentation in which:
    - Mercer XLab Benchtop users bonded over consistent appearances in the shared Mercer XLab space, human and physical resources, electronic parts, and opportunities to learn beyond the course.
    - Personal Instrumentation users bonded over figuring out workarounds, debugging, and through the portability of their instrumentation.

Personal Instrumentation user comments:

- Users reflected on the benefits of personal instrumentation:
    - The most common benefits mentioned were portability and accessibility, anytime, anywhere.
    - Students could fit their work into their lives instead of bending their lives around their work.
    - The egalitarian learning space enabled crowd source information from other students using the same measurement device.
    - Students were able to go to each other outside of the lab and get real time feedback/answers to questions.
- Users also reflect on challenges:
    - Some personal instrumentation software was noted to be “buggy” and not consistently reliable depending on their circuit.
    - Instrumentation also did not have a wide range of supply voltage and thus influenced device design based on the supply voltage limit. In some ways limitation inspires a kind of creativity and reflects real engineering practice with design specifications.
    - This may reflect approaching the limitations of the measurement device without yet developing the ability to identify these issues as true software bugs or misunderstanding of device limitations.
    - One student noted that personal instrumentation was not used in industry. Professional development is hindered by its use if skills are not translated to benchtop equipment.

Benchtop user comments:

- Users reflected on the benefits of Mercer XLab Benchtop instrumentation:
    - Students directly tied learning how to use benchtop, industry standard equipment to professional development.
    - The social space of the Mercer XLab was extremely encouraging and welcoming. Though lab objectives were accomplished, students felt a sense of community in space, sometimes leading to other uses or explorations (like PCB printing, access to a full-time technician for support, access to Mercer XLab student-workers for support often further along in matriculation or skillset, learning to solder, or Student-Club Workshop participation)
- Users reflected on the challenges of Mercer XLab Benchtop instrumentation:
    - The Mercer XLab was not as accessible 24/7 as they would have liked.
    - Benchtop users perceived a steeper-than-expected learning curve in comparison to previous experiences with personal instrumentation.

Conclusions and Next Steps

Competence and Confidence:

1. Students achieved nearly identical competence before starting Alpha (Traditional) Lab or Omega (Design) Labs and before choosing teammates in the Proof of Skill Experimental Measurement and Instrumentation skillset.
2. Survey results correlated to student performance in Proof of Skills and their confidence before and after Proof of Skills are related to their choice of lab: Alpha (Traditional) Lab or Omega (Design) Labs. Students using Mercer XLab Benchtop instrumentation conveyed High Confidence in a higher percentage than Personal Instrumentation students. All Mercer XLab Benctop students choose Omega (Design) Labs. Personal Instrumentation users conveyed higher Moderate-High Confidence, however, with ~16% deciding to participate in Alpha (Traditional Labs).

Instrumentation Choice Trends: Personal Instrumentation and Mercer XLab Effects

3. Results show that many students preferred the convenience of the portable measurement devices, whether they worked in the Mercer XLab or other locations.
4. A subset of the students had a strong preference for the benchtop equipment in the Mercer XLab. These students had a stronger-than-average interest in measurement tools and viewed the opportunity as professional development.
5. The lack of random selection of instruments for this study more likely correlates the perception of professional development. Students perceive the Omega (Design) Lab as professional development in the same way they perceived Mercer XLab benchtop selection.
6. The Mercer XLab provided students with increased access to bench-top equipment for longer hours and continuous support from skilled student-workers and a technician. Key findings include the lab's function as a communal learning space, contrasting with the siloed, hierarchical nature of traditional labs and lectures. Students collaborated freely, engaging with peers in various stages of matriculation, student-clubs, teaching assistants, and professors.

Next Steps:

7. While Omega Labs was distributed to five courses in Fall 2024 and Spring 2025, the direct comparison of quantitative data in the Mercer XLab vs. Personal Instrumentation did not apply to every course. Thus, in the future, at least three of the five courses that use some version of in-person and portable instrumentation will be investigated with random selection. Surveys across every course will be uniformly distributed to find correlations across the core courses, Introduction to ECSE (ECSE-1010), Electric Circuits (ECSE-2010), and Computer Components and Operations (ECSE-2610).
8. Students selected their instrument choice. It was not a random selection. Thus, students with strong ambition toward professional development selected both Mercer XLab Benchtop instrumentation and Omega (Design) Labs. This self-selection can be avoided in future studies. A random selection of instrumentation for students would show the effect of the instrument alone on their mindset in a clearer way.

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