WIP: Preliminary Findings on the Effectiveness of Hands-On Activities and Reflection Exercises on Building Curiosity and Design Awareness

Eunbyul Park, University of Illinois at Urbana - Champaign
Chandrasekhar Radhakrishnan, University of Illinois, Urbana-Champaign
Prof. Jonathon Kenneth Schuh, University of Illinois at Urbana - Champaign

Jonathon Schuh is a Teaching Assistant Professor in the Electrical and Computer Engineering Department at the University of Illinois at Urbana-Champaign. He received his Ph.D. in Theoretical and Applied Mechanics from the University of Illinois in 2018 an

Prof. Olga Mironenko, University of Illinois at Urbana - Champaign

Dr. Olga Mironenko is a Teaching Assistant Professor with the Department of Electrical and Computer Engineering at University of Illinois Urbana-Champaign. She received a specialist degree in Physics from Omsk F.M. Dostoevsky State University, Russia in 2009, and she received a Ph.D. degree in Electrical and Computer Engineering from University of Delaware in 2020. Her current interests include improvement of introductory analog signal processing and power systems courses, training for graduate teaching assistants, and mentoring of under-represented students in ECE.

Dr. Christopher D. Schmitz, University of Illinois at Urbana - Champaign

Christopher D. Schmitz received his Ph.D. in Electrical and Computer Engineering from the University of Illinois in 2002.

Yang Victoria Shao, University of Illinois at Urbana - Champaign

Yang V. Shao is a Teaching Associate Professor in electrical and computer engineering department at University of Illinois Urbana-Champaign (UIUC). She earned her Ph.D. degrees in electrical engineering from Chinese Academy of Sciences, China. She has worked with University of New Mexico before joining UIUC where she developed some graduate courses on Electromagnetics. Dr. Shao has research interests in curriculum development, assessment, student retention and student success in engineering, developing innovative ways of merging engineering fundamentals and research applications.

Arijit Banerjee, University of Illinois at Urbana - Champaign
Dr. Rebecca Marie Reck, University of Illinois at Urbana - Champaign

Rebecca M. Reck is a Teaching Associate Professor of Bioengineering at the University of Illinois Urbana-Champaign. Her research includes alternative grading, entrepreneurial mindset, instructional laboratories, and equity-focused teaching. She teaches biomedical instrumentation, signal processing, and control systems. She earned a Ph.D. in Systems Engineering from the University of Illinois Urbana-Champaign, an M.S. in Electrical Engineering from Iowa State University, and a B.S. in Electrical Engineering from Rose-Hulman Institute of Technology.

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Abstract

This work-in-progress study examines electrical engineering students' learning experiences following changes to an electronic circuits laboratory class. Experiential learning is an effective strategy in engineering, fostering problem-solving skills and the application of theoretical knowledge [1, 2]. Complementing this, structured reflection helps students integrate new knowledge with prior understanding and deepen their learning experience [3, 4]. In this work a combination of hands-on activities, course staff led demonstrations, and reflection exercises is used in an electronic circuits lab to help students synthesize multiple concepts, relate them to practical applications, and assess the trade-offs (pros and cons) inherent in engineering design decisions. These learning objectives also align with KEEN's Entrepreneurial Mindset (EM) framework, which has been integrated into numerous engineering curricula in recent years.

1 Introduction

An important goal of engineering education is to prepare students to design solutions to real-world problems involving system design. An important aspect of system design is the ability to identify relevant performance parameters, evaluate trade-offs within a solution space, and select among non-unique design alternatives that satisfy application-specific constraints.

As students progress through the curriculum, they move from analytical problem solving to design under constraints, trade-off analysis, and ultimately complete, application-driven system design. Through this progression, students' understanding of engineering trade-offs and system-level considerations is expected to mature over time. In earlier work [5], this laboratory course was redesigned to support this progression by emphasizing hands-on activities and instructor-led demonstrations intended to help students connect concepts across prior circuit course and the evolution of concepts across curriculum.

Reflections are a well-established mechanism for improving student learning, conceptual understanding, and academic performance [2]. Prior work has demonstrated the effectiveness of reflective activities in electrical engineering education, including the use of exam-based reflections to improve performance in introductory circuits courses [6], structured post-exam and self-assessment reflections to promote self-directed learning in Electrical and Computer Engineering (ECE) curricula [7], and reflective exercises designed to deepen conceptual understanding and improve outcomes in digital and analog electronics courses [4].

In this work, we intentionally combine hands-on laboratory activities with reflection exercises to support an expanded set of learning objectives. Specifically, reflections and targeted lab prompts are used to examine whether students are able to synthesize concepts across multiple prior courses, explore and articulate engineering design trade-offs, recognize interdependencies among system elements, and reflect on their own learning. Student reflections and lab artifacts are analyzed to assess the extent to which these objectives are achieved.

2 Lab Overview

The ECE circuits curriculum at University of Illinois, Urbana-Champaign, progresses from foundational analysis to advanced design. Early-level courses, Introduction to Electronics (ECE 110) introduce basic circuit concepts, modeling, measurement, and analytical techniques. Intermediate courses such as Electronic Circuits (ECE 342) and Electronic Circuits Lab (ECE 343) build on this foundation by introducing transistor- and diode-based circuits, engaging students in design activities and laboratory implementation, and exposing students to the role of increasing constraints.These classes also serve as a prerequisite for follow-up elective classes in the circuits area. The elective classes include either a design lab or or several weeks of design project.

The course interventions and initial results in this paper are in relation to the junior-level classes ECE 343. This course is typically taken after students have developed foundational knowledge across core areas of electrical engineering and are able to analyze and solve engineering problems independently. At this stage, students are also beginning to explore areas of specialization. The electronic circuits laboratory therefore provides a timely setting for reflection on prior learning, exposure to subsequent coursework, and engagement with design challenges under varying constraints.

The lab under consideration is centered on the design and analysis of DC–DC converters, situating these circuits within the broader context of a complete AC–DC power supply. The AC–DC converter is designed using principles of a zener diode based reference voltage, followed by a Low-dropout (LDO) regulator stage. The lab consists of the following components:

1. **Procedural exercises** that guide students through circuit design, analysis, and implementation.
2. **Course-staff demonstrations** of a related circuit drawn from a follow-on power electronics laboratory, designed to illustrate noise–area trade-offs in a broader system context.
3. **Comparative questions and Reflective exercises** that help students integrate lab activities.

The primary focus of this paper is on comparative questions and reflection exercises intended to guide students in appreciating the progression of concepts through the curriculum, assessing design trade-offs, and understanding the interdependencies among system components. Students engage in answering comparative questions and completing a reflection exercise upon the completion of circuit design and implementation and course-staff led demonstration. The questions are designed around different types of power converter circuits that students have seen in prior classes and will also see in future classes, namely,

1. Voltage dividers
2. Zener-diode-based converters
3. Switching converters

Students engage in answering comparative study questions during the lab and complete reflection exercises outside the lab. Together, these activities help students articulate observed design trade-offs, connect the lab experience with prior coursework, and reason about the system-level implications of their design decisions.

3 Reflection Activities and Intended Learning Outcomes

This section reports preliminary assessment findings using a post-lab anonymous Likert-scale survey and student written reflections. The Likert-scale survey provides a preliminary view of student perceptions of the lab changes. Qualitative observations from an initial review of reflection responses are discussed in more detail in this section. A total of 26 students participated in the survey, and 41 students provided informed consent for their reflections to be used in this study. The reflections were collected and anonymized prior to analysis.

3.1 Preliminary Survey Results

This section presents the results of the survey conducted at the end of the semester. The survey was designed to assess the usefulness of the assignment in supporting a subset of EM learning objectives. We used a subset of the behavioral outcomes representative of an EM from [8, 9] to create survey questions.

Table 1 lists the survey prompts together with their summary statistics, while Fig. 1 shows the distribution of student responses across the Likert-scale categories. Taken together, they indicate generally favorable responses to items related to knowledge integration, reflection, and systems-level understanding, with modest variation across responses. It should be noted that the sample size is small ($N = 26$), so firm conclusions cannot be drawn. Instead, the statistical analysis and accompanying plots provide indicative evidence that the assignments may be perceived as supporting the stated objectives related to knowledge integration, reflection, pros and cons in design, and systems-level understanding.

Table 1: Student Survey Responses $N = 26$

Survey Question	Mean (μ)	Std. Dev. (σ)	Std. Err. ($\sigma/\sqrt{N}$)
Encourage students to recognize and explore knowledge gaps on different topics (Q1).	3.808	0.680	0.133
Required reflection on preconceived ideas, thought, accepted solutions taught in previous courses (Q2).	3.923	0.675	0.132
Provide opportunities for identifying interesting topics to explore (Q3).	3.923	0.549	0.108
Illustrate that engineering design decisions have pros and cons (Q4).	4.385	0.788	0.155
Opportunities to articulate an understanding of a topic (Q5).	4.889	0.261	0.051
Demonstrate the importance of considering a topic from different perspectives (Q6).	3.640	0.546	0.107
Demonstrate the role of various components connect to form a complex system (Q7).	4.231	0.576	0.113
Demonstrate how many concepts connect to solve a complex problem (Q8).	4.077	0.730	0.143
Prompt students to integrate and synthesize different kinds of knowledge (Q9).	3.692	0.722	0.142
Connect content from multiple courses (Q10).	3.769	0.799	0.157
Illustrate the importance of considering multiple viewpoints to a problem (Q11).	3.769	0.639	0.125

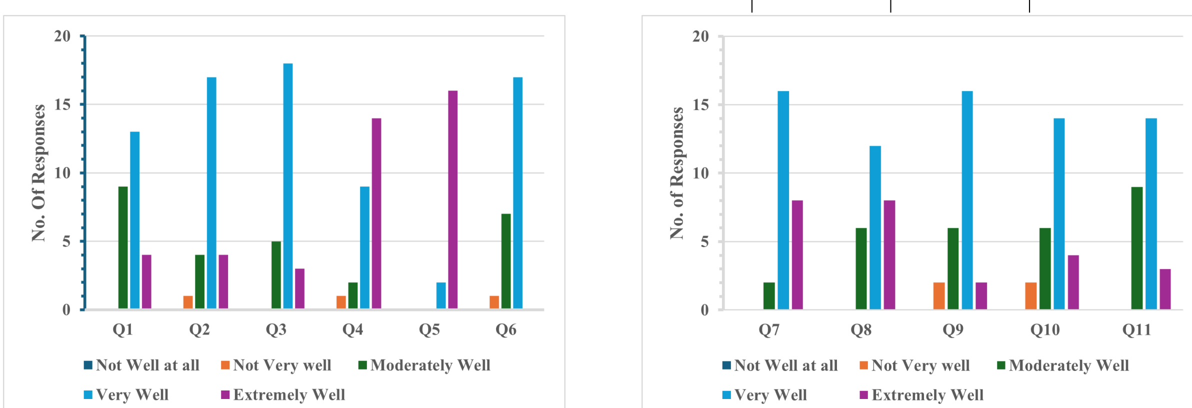

Figure 1: Likert scale survey responses for questions on how students perceived lab activities and reflection assignment.

3.2 Preliminary Reflections Analysis

Table 2: Reflection prompts and evidence sought - importance of trade-offs.

Reflection Prompt Focus	Evidence in Student Responses
Evolution of power converter concepts through curriculum	Identification of classes and context of the power converter.
Applications and limitations of different DC–DC converter types	Identification of appropriate use cases for different converter architectures and justification for why multiple DC–DC converter types are necessary
Identification of additional design parameters and resulting trade-offs	Introduction of new design parameters and explanation of how these parameters introduce trade-off considerations
Importance of understanding design constraints	Reflection on how application-specific constraints shape feasible designs and influence engineering decision-making

Table 2 summarizes the reflection prompts and associated evidence considered in this study. The reflection analysis is ongoing. One qualitative researcher selected 10 of 41 from Spring 2025 semester reflections at random and analyzed them using open coding [10] to explore students' perceptions of overall lab learning experiences and specific activities, such as soldering and instructors' demonstrations, and their understanding of trade-offs. During the initial cycle, they identified patterns in students' understanding and articulation of the interconnectedness among elements and trade-offs, identifying concept connections across courses, and limitations and applications of different DC-DC converters. These will be discussed in detail below. Currently, they continue to analyze with thematic coding method [10] the rest of the reflections iteratively to check whether these early patterns are aligned with the rest of the reflections and to examine further if there are other emerging patterns to evaluate students' learning experiences according to the proposed learning objectives for Lab 3, including practical application to real-world contexts, and assessing design parameters and resulting trade-offs. Section 3.2.1 presents the results of the preliminary analysis.

3.2.1 Reflection Examples and Analysis

The preliminary findings of the analysis are aligned with the survey results. First, they show that the students were able to connect what they learned from previous courses to the lab learning and then further expanded on it during the lab.

> *"Additionally, we have seen these circuits before without really understanding their limitations. When looking at circuits through a power conservation lens, we see that both of these implementations should only be used in applications where power loss is not a major factor. In ECE110, I never considered that power was lost through one of the resistors in a voltage divider since we had a very high wattage power supply. Now, I only consider voltage divider circuits where power delivery is not a factor."*

They also demonstrate students' understanding of the interconnectedness of elements and the mutual influences among them to form a complex system.

> *"A voltage divider is very simple, but it is load dependent, so when the load changes the voltage and current going to the load changes as well." "If we wanted to implement a low-noise DC-DC circuit for a phone, we would need to make our circuit smaller and more precise, even at the cost of efficiency. But if we wanted our circuit to be more efficient and didn't care about the size, then we would build an LC circuit. So it is all about prioritizing what functionality we want from the circuit."*

Furthermore, the preliminary findings indicate some qualitative differences among students' understanding of the trade-offs. First, some students simply stated the limitations they learned from the lab in an as-a-matter-of-fact manner.

> *"As for limitations of voltage dividers, they are inefficient for power conversion, even though their design is simple. As for limitations of Zener diode-based DC-DC converters, these circuits provide a stable voltage effectively, but their efficiency is low under different loads."*

Second, some students could explain the limitations they learned in real-world contexts, demonstrating how such limitations would be applied in real-world.

> *"LDO converters are very stable even with different loads and have a large output current, but have a significant power loss over the BJT. They are often found in consumer electronic devices because of their small size and reliability."*

> *"... high power components such as BJT's dissipate a lot of heat under a full load. As such heatsinks improve the reliability of the circuit but are often big in size and may cost a little more. For small devices such as cell phones you can allow it to cool down passively but for larger scaled industrial applications, you need to think about how to manage the heat given off by the components."*

Lastly, some students were able to articulate further the appropriateness of certain elements depending on specific objectives and contexts. In this case, students seemed to focus on what they needed to achieve in a given context and then prioritize certain limitations when making design choices.

> *"This lab showed me that each of these converters has a certain purpose with different applications. Even if some of the converters aren't as efficient as others, they serve a purpose for certain devices where their needs are different from one to the next."*

It should be noted that it does not necessarily mean that any one type of the responses indicates a more advanced understanding compared to the other two. However, it is rather to suggest that the preliminary findings indicate that there may be qualitative differences in how students demonstrate their knowledge of trade-offs from the lab learning.

4 Limitations and Future Plan

The findings presented in this paper are preliminary and should be interpreted accordingly. First, the reflection analysis is ongoing, therefore, these findings should be viewed as initial insights rather than definitive conclusions. The themes reported here may be refined as additional data are examined. Second, the findings draw exclusively on students' written reflections. No additional data sources were collected to examine the lab learning experience during the Spring 2025 semester. Consequently, the robustness of these findings is relatively constrained. Some additional refinements to the lab were implemented in Fall 2025, and data collection continued during that term. Further data collection is planned for Spring 2026, along with focus group interviews to complement the reflection exercises. These steps are expected to increase the amount of data available and enable more robust analysis, leading to clearer and more concrete findings. Also, as mentioned earlier the survey sample size is small and there was no control group, so these findings should be interpreted cautiously. Designing an appropriate comparison group that does not share the same learning experiences, while remaining fair to students, is an important challenge that is currently being explored.

5 Conclusion

This work-in-progress paper discusses initial insights drawn from student surveys and reflections collected in a junior-level electronic circuits laboratory course. Preliminary analysis of the survey results suggests that students perceived lab activities, demonstrations, and reflection exercises as contributing to knowledge integration, reflection, and systems-level understanding. Analysis of more reflection exercises is ongoing. Further refinements to the course incorporating elements of KEEN framework were carried out in Fall 2025. Additional data have been collected and will continue to be gathered in future semesters. In addition to surveys and reflection exercises, focus group interviews are also being planned for future semesters.

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