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From Circuits to Choices: Leveraging Foundational Electrical Circuits Teaching to Support Informed Elective Decision-Making in Electrical Engineering

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1. Introduction

Recent studies have suggested that undergraduate engineering students often struggle with elective course selection due to various factors, including information gaps, limited technical advising and guidance, and perceived tradeoffs between risk and reward [1]-[5]. Moreover, research indicates that professors and classes are among the most influential factors shaping students' intra-major specialization choices [6]-[8], although the curricula in most universities are not typically designed to intentionally influence such decisions. Effective elective decision-making is of essential importance since it directly influences students' academic trajectories and both short- and long-term career development.

Foundational electrical circuits courses are widely regarded as the gateway to electrical engineering. They serve as prerequisites for most electrical engineering electives, thus forming the fundamental basis of nearly all fields in electrical engineering. Moreover, these courses introduce students to system-level thinking while developing essential problem-solving and analytical skills. Beyond providing foundational knowledge, to what extent can foundational electrical circuits courses support electrical engineering students in making informed decisions about their elective course selections?

This paper investigates the hypothesis that foundational electrical circuits teaching can support informed elective decision-making among electrical engineering students by connecting key theoretical topics to real-world applications and providing guided mentoring. To this end, we propose pedagogical practices to connect electrical circuit concepts, such as Thévenin's theorem, maximum power transfer theorem, and capacitive and magnetic coupling, to elective areas and courses through exposure to real-world contexts, practical applications, and guided mentoring focused on elective course areas and career pathway opportunities in electrical engineering. An anonymous survey with over 50 electrical circuit students at the Colorado School of Mines was used to gather perceptions, feedback, and validate the effectiveness of the proposed pedagogical practices as well as provide recommendations for future work.

2. Methodology

As of 2025, the undergraduate electrical engineering program at the Colorado School of Mines comprised four main elective areas: Antenna and Wireless Communications (AWC), Integrated Circuits and Electronics (ICE), Information & Systems Sciences (ISS), and Power and Energy Systems (PES), whose elective courses are listed in Table I. Before taking most elective courses, students are required to take prerequisite core courses such as EENG 282 (Electrical Circuits).

EENG 282 is a one-semester, 4-credit-hour core course that includes lectures and hands-on laboratory activities. It covers DC and AC circuit analysis, Ohm's Law, resistors, inductors, capacitors, equivalent resistance and impedance, Kirchhoff's Laws, Thévenin's and Norton's theorems, superposition and source transformation, power and energy, maximum power transfer, first order transient response, phasors, and steady-state analysis of single-phase and three-phase AC power circuits.

Although core engineering courses provide the fundamental basis of different elective areas, they may lack clear connections to real-world contexts and applications. As a result, students may become disengaged and lose interest in elective courses and their majors [9]-[10]. Many electrical circuits textbooks, for example, introduce important topics, such as Thévenin's theorem in a largely theoretical manner, with little or no connection to practical applications.

Table I – Electrical engineering electives by area at the Colorado School of Mines as of 2025.

<table>
<tr><th>AWC</th><th>ISS</th><th>ICE</th><th>PES</th></tr>
<tr><td>Electromagnetic Field and Waves</td><td>Data Science for EE</td><td>Semiconductor Device Physics & Design</td><td>Introduction to High Power Electronics</td></tr>
<tr><td>Introduction to Antennas</td><td>Modern Control Design</td><td>Introduction to VLSI Design</td><td>Interconnection of Renewable Energy</td></tr>
<tr><td colspan="2">Wireless Communications</td><td>Advanced Digital Design</td><td>Power Systems Analysis</td></tr>
<tr><td>Passive RF & Microwave Devices</td><td colspan="2">Digital Signal Processing</td><td>-</td></tr>
<tr><td>Active RF & Microwave Devices</td><td>Introduction to Computer Vision</td><td>Elements of Computing Systems</td><td>-</td></tr>
<tr><td>Computational Electromagnetics</td><td>Introduction to Robotics</td><td>Interdisciplinary. Microelectronics Processing Lab</td><td>-</td></tr>
</table>

The objective of this study is to assess the effectiveness of two teaching interventions designed to support informed elective decision-making among electrical engineering students, as described below.

2.1. Application-Oriented Problems and Materials

The first teaching intervention investigated in this study involved the use of application-oriented classroom problems and materials to better connect electrical circuits topics to elective areas and real-world applications. Figure 1 illustrates a comparison between a traditional problem and an application-oriented problem involving Thévenin's theorem in the PES elective area. The traditional problem presents a circuit without any specific context, whereas the application-oriented problem presents the same circuit but adds context regarding the circuit topology, nodes and elements, as well as a practical PES application (i.e., determining the voltage drop across a real load). Similarly, Figure 2 illustrates a comparison between a traditional problem and an application-oriented problem involving the maximum power transfer theorem in the AWC elective area using a circuit with a transmitter and an antenna connected through a lossless transmission line. These types of problems helped students better understand the context, significance, and applications across different elective areas in electrical engineering.

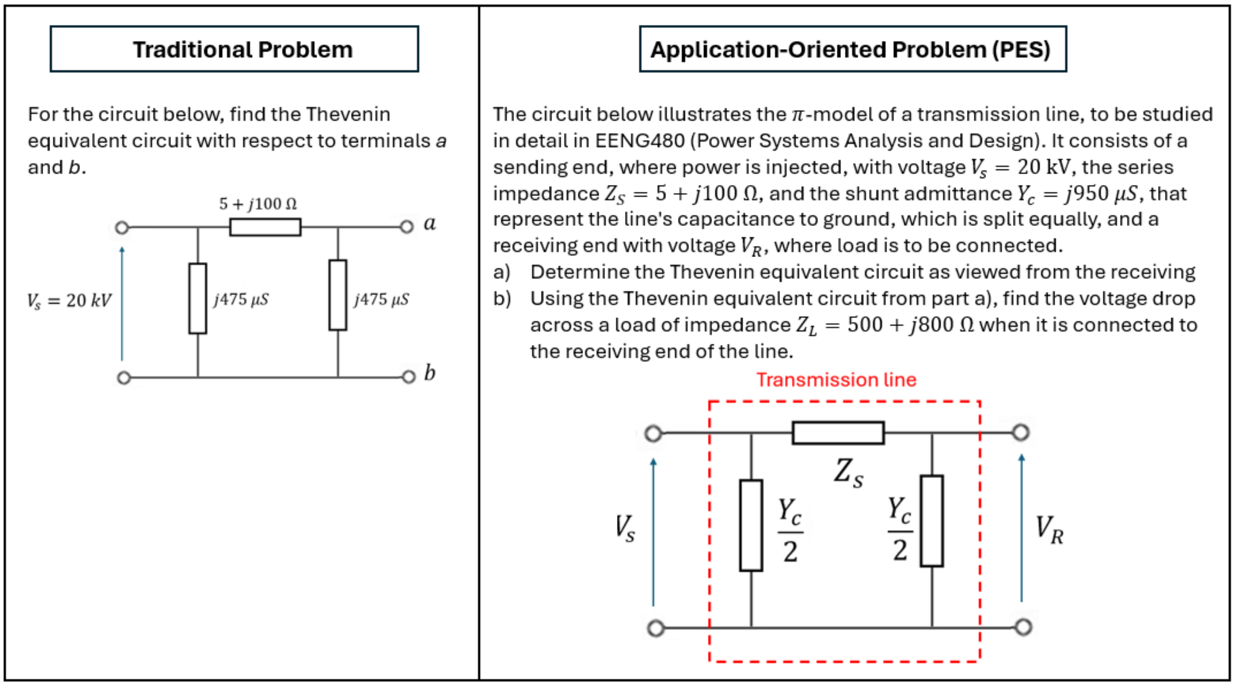

Figure 1 – A traditional vs. an application-oriented problem in the PES elective area.

In addition to the use of application-oriented problems described above, students were exposed to real-world circuit applications in different elective areas. Figure 3 illustrates a theremin application from theoretical concept to practical implementation. Initially, the concept of a theremin as musical instrument played without any physical contact was introduced. Students were then asked to describe potential electrical circuits concepts that could be used to vary the sound frequency based on the performer's hand movement. Then, an equivalent circuit based on the principle of mutual capacitance was presented. This first activity was designed to stimulate curiosity and initiate discussions on elective courses and career opportunities in the AWC area. Next, an alternative and simpler theremin implementation using phototransistors instead of mutual capacitance was presented. Students were introduced to circuit schematics and Gerber files and interacted with a physical circuit prototype. This second activity sparked curiosity and prompted discussions about elective courses and career opportunities in the ICE area. Table II lists additional materials (white papers, online articles, research papers, and videos) that connect foundational electrical circuit concepts with real-world applications across different electrical engineering elective areas presented to students.

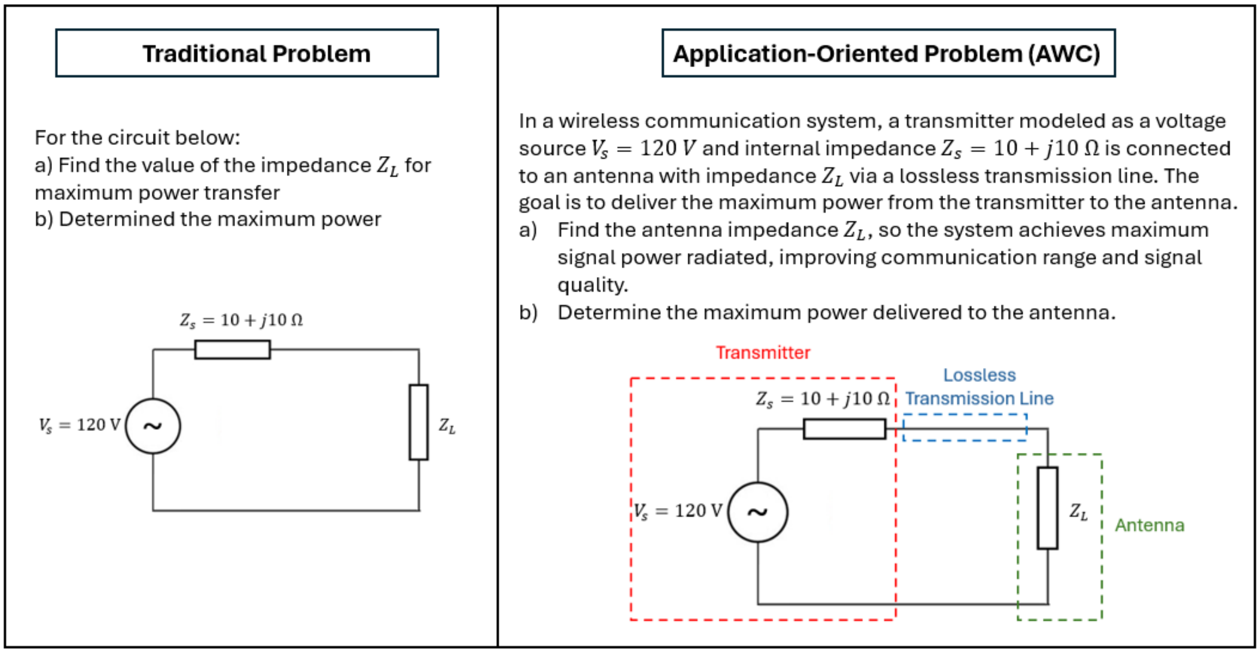

Figure 2 – A traditional vs. an application-oriented problem in the AWC elective area.

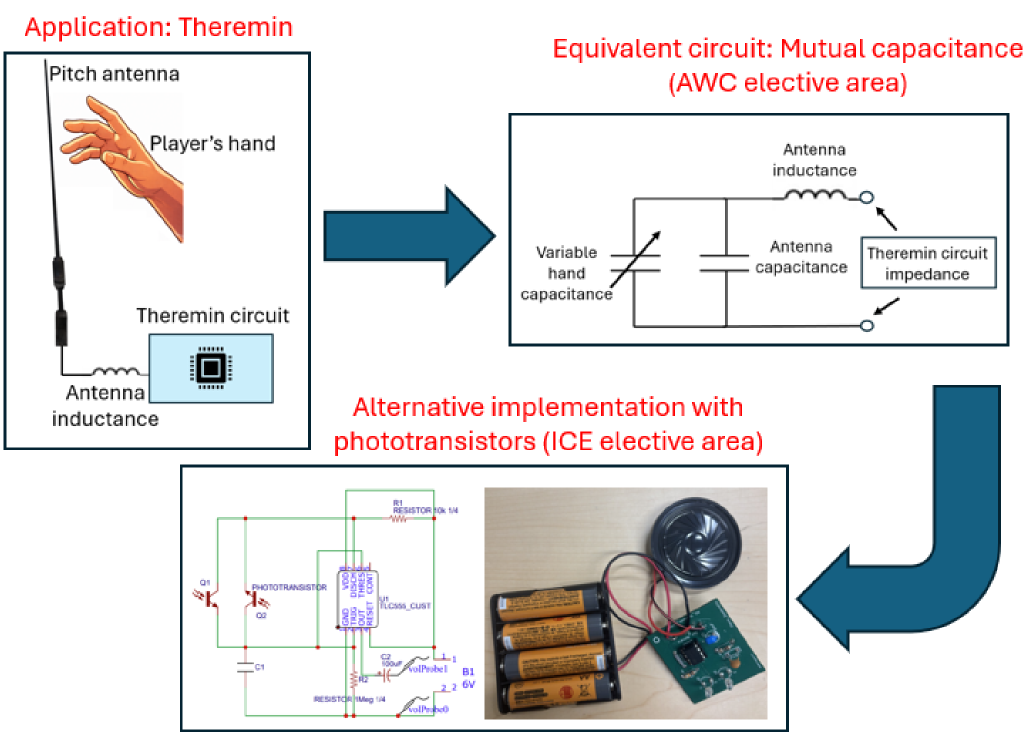

Figure 3 – A theremin application from concept to implementation [11].

Table II – Additional circuit applications across different electrical engineering elective areas.

Concept	Application	Elective Area	Reference
Magnetic coupling	Traffic induction loops	AWC	[12]
Capacitive coupling	Touch screens	ICE	[13]
Magnetic and capacitive coupling	Power transmission line modeling	PES	[14]
Magnetic coupling	Induction stoves	AWC	[15]
Magnetic coupling	Power transformers	AWC, PES	[16]
Magnetic coupling	Wireless battery charging	AWC	[17]
Thévenin's theorem	Short circuits in transmission lines	PES	[18]
Analogous systems	General first and zero order chemical reactions	ISS	[19]
Analogous systems	Water processing plant control	ISS	[20]
Phasors	Voltage and frequency control	PES	[21]

2.2. Guided Mentoring

In addition to the in-class activities described above, students were offered guided one-on-one mentoring in electrical engineering elective areas before and after course lectures and during three office hours a week. The mentoring sessions focused on providing background and detailed information on the AWC, ICE, ISS, and PES elective areas at the Colorado School of Mines, the various elective courses offered within each area, as well as information about student clubs, scholarships, technical challenges, and research and career opportunities (e.g., job markets, companies, and salaries) within each area. During the mentoring sessions, it was observed that the electrical circuits course helped students identify their technical strengths and interests within the major. For example, many students who enjoyed hands-on circuits laboratory experiments demonstrated higher interest in the ICE elective area. On the other hand, many students that enjoyed learning about phasors and three-phase systems demonstrated higher interest in the PES elective area.

3. Results

Fifty two out of 92 electrical circuits students participated in an in-class research survey in Fall 2025. The survey aimed to: (1) Evaluate their familiarity with elective areas before and after taking the circuits course; (2) Evaluate their interests in each elective area before and after taking the circuits course; and (3) Evaluate the effectiveness of the proposed pedagogical practices in connecting foundational electrical circuit concepts to elective areas and courses. Figure 4 shows students' responses to a question about how the circuits course increased their familiarity with the four elective areas. More than 90% of the students reported that the circuits course increased their familiarity across the four elective areas.

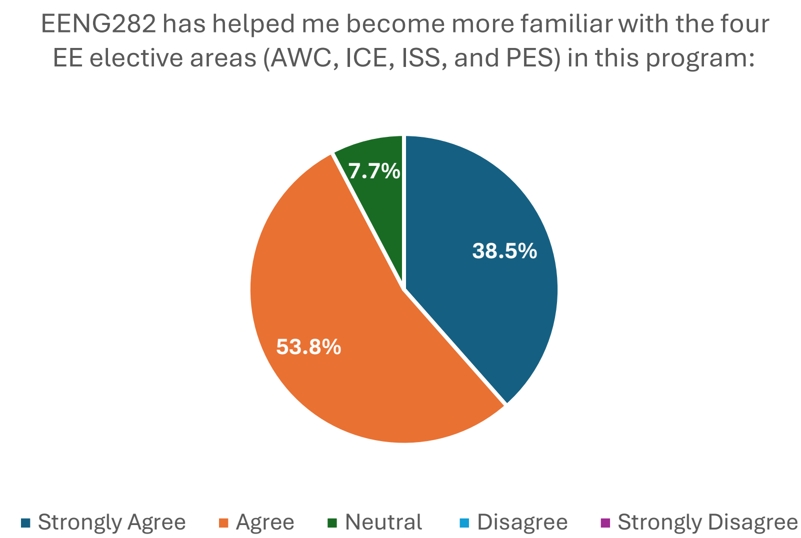

Figure 4 – Students' responses on how the circuits courses increased their familiarity with the elective areas.

Figure 5 shows students' familiarity with each elective area, measured using average Likert scale, before and after taking the circuits course. It can be observed that the circuits course helped students gain significantly greater familiarity in each elective area.

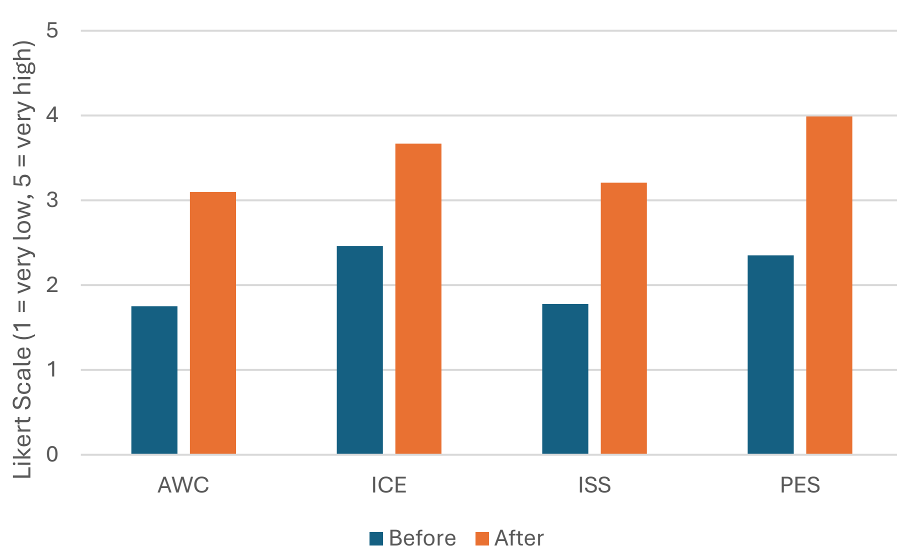

Figure 5 – Students' familiarity with each elective are before and after the circuits course.

Figure 6 shows that there was a significant increase in interest in each elective area after taking the circuits course. None of the elective areas reported a decrease in interest. This is particularly positive, given that electrical engineering students at the Colorado School of Mines can take elective courses across different elective areas. Moreover, this may be beneficial for student retention, since increased and sustained interest in elective areas is likely to encourage students to remain engaged and persist in the electrical engineering major.

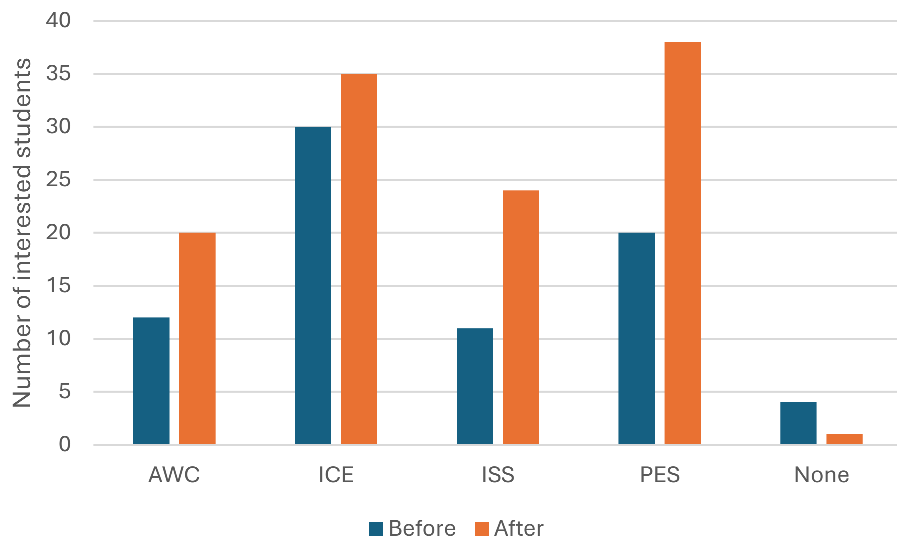

Figure 6 – Students' interest in each elective area before and after the circuits course.

The survey also asked students about their understanding of how key electrical circuits concepts (Thevenin's and Norton's theorems, the maximum power transfer theorem, and magnetic and capacitive coupling) connect to real-world applications in different elective areas. Results show that more than 80% of the students clearly understand these connections for each of the aforementioned concepts, as shown in Figure 7.

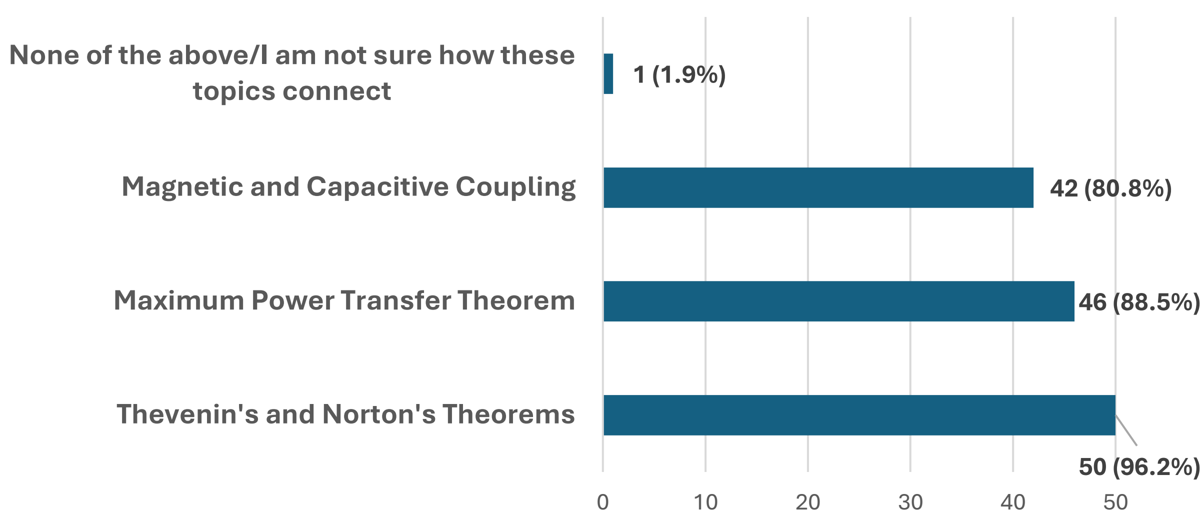

Figure 7 – Students' responses reflecting their understanding of how key electrical circuits concepts connect to real-world applications in different elective areas.

Moreover, over 90% of the students who completed the survey agreed that class examples illustrating real-world applications helped them better understand the topic and increase their interest.

Finally, the survey assessed the effectiveness of guided mentoring in electrical engineering elective areas. About 56% of the respondents indicated that they had received guided mentoring. As shown in Figure 8, nearly 77% of the mentored students reported that the mentoring activities helped them better understand the AWC, ICE, ISS, and PES elective areas and the courses in these areas.

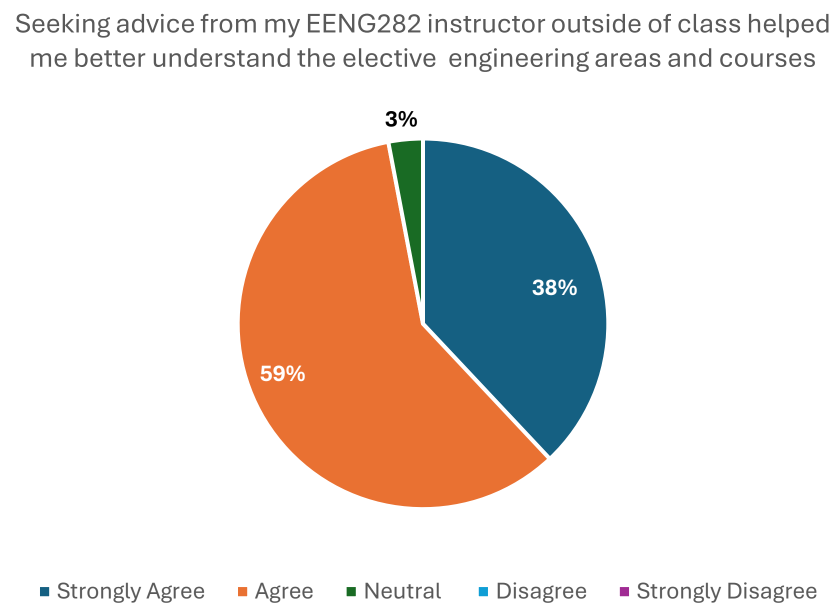

Figure 8 – Students' responses regarding the impact of guided mentoring on understanding electrical engineering elective areas and courses.

4. Conclusion and Future Directions

This study described pedagogical practices that can be used to connect key foundational electrical circuits concepts to electrical engineering elective areas, thereby helping students make informed decisions about elective areas, courses, and career pathways. First, the study highlights the impact of application-oriented problems and materials in increasing students' interest and helping them connect theoretical concepts to real-world and everyday applications. Survey results suggest that students were able to relate Thevenin's and Norton's theorems, the maximum power transfer theorem, and inductive and capacitive coupling to real-world applications across different electrical engineering elective areas. Moreover, students reported a significant increase in interest in each elective area after taking the circuits course, which could be beneficial to increase student retention and engagement within the electrical engineering major. Second, the study highlights the importance of guided, one-on-one mentoring on elective areas and courses, as well as research and career opportunities within them. Survey results indicate that this type of mentoring helps broaden students' understanding of each elective area and their associated courses.

Future studies can be conducted to investigate the impact of the proposed pedagogical practices on long-term enrollment as well as students' performance and interest in different elective courses. Moreover, the associated impacts on students' retention in the electrical engineering major could also be investigated.

References

[1] S. Chaturapruek, T. Dalberg, M. E. Thompson, S. Giebel, M. H. Harrison, R. Johari, M. L. Stevens, and R. F. Kizilcec, "Studying undergraduate course consideration at scale," *AERA Open,* vol. 7., 2021.

[2] T. Cardador, K. Jensen, G. Lopez-Alvarez, I. Miller, H. Chiou, A. J. Kunze, and S. Kim, "Board 263: Elective Track Choice and Career Attitudes in Engineering Undergraduate Education: Antecedents, Gender Differences, and Implications," *in Proc. 2023 ASEE Annual Conference & Exposition*, Baltimore, MD, USA, Jun. 25-28, 2023, Paper no. 42710, doi: 10.18260/1-2-42710.

[3] P. Shekhar and A. Huang-Saad, "Examining engineering students' participation in entrepreneurship education programs: implications for practice," *International Journal of STEM Education*, vol. 8, art. no. 40, Jun. 2021, doi: 10.1186/s40594-021-00298-9.

[4] J. R. Reisel, "An Exploration of the Use of Technical Electives in Engineering Curricula," *in Proc. 2023 ASEE Annual Conference & Exposition*, Baltimore, MD, USA, Jun. 2023, doi: 10.18260/1-2-42623.

[5] C. J. Reagle and O. Barton Jr., "Assessing the Impact of Student Choice of Electives," *in Proc. ASEE Southeast Section Conference*, Arlington, VA, USA, Mar. 2023, paper no. 44988, doi: 10.18260/1-2-44988.

[6] H. Fricke, J. Grogger, and A. Steinmayr, "Exposure to academic fields and college major choice," *Econ. Educ. Rev.*, vol. 64, pp. 199–213, Jun. 2018

[7] T. L. Trolian, E. A. Jach, J. M. Hanson, and E. T. Pascarella, "Influencing academic motivation: The effects of student–faculty interaction," *J. College Student Dev.*, vol. 57, no. 7, pp. 810–826, Oct. 2016.

[8] B. Ma, M. Lu, Y. Taniguchi, and S. Konomi, "Investigating course choice motivations in university environments," *Smart Learn. Environ.*, vol. 8, art. no. 31, Nov. 2021.

[9] M. Prince, “Does active learning work? A review of the research,” *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, Jul. 2004.

[10] S. Sheppard, K. Macatangay, A. Colby, and W. M. Sullivan, *Educating Engineers: Designing for the Future of the Field*. San Francisco, CA, USA: Jossey-Bass, 2009.

[11] UCF Antenna Capacitance and Calculators. Available: https://www.ece.ucf.edu/seniordesign/su2012fa2012/g01/tools.html [Accessed Aug. 2, 2025].

[12] How Traffic Lights Detect Cars Are Waiting for the Light to Change. Available: https://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/how-does-a-traffic-light-detect-that-a-car-has-pulled-up-and-is-waiting-for-the-light-to-change.htm [Accessed Aug. 26, 2025].

[13] Capacitive Touch Screen: Types, Principles and Advantages. Available: https://www.iqsdirectory.com/articles/membrane-switch/capacitive-touch-screens.html [Accessed Oct. 1, 2025].

[14] Typhoon Hil Transmission Line. Available: https://www.typhoon-hil.com/documentation/typhoon-hil-software-manual/References/transmission_line.html [Accessed Oct. 3, 2025].

[15] What is induction cooking and how does it work? Available: https://www.whirlpool.com/blog/kitchen/what-is-induction-cooking.html [Accessed Oct. 3, 2025].

[16] Basic Inductance Principles in Transformers. Available: https://eepower.com/technical-articles/transformer-operating-principles/# [Accessed Sep. 25, 2025].

[17] Wireless Li-Ion Battery Charger Circuit. Available: https://www.homemade-circuits.com/how-to-make-inductive-li-ion-battery/ [Accessed Sep 29, 2025].

[18] R. Aljarrah, M. Karimi, H. Marzooghi, S. Alnaser, M. Al-Omary, Q. Salem, and S. Harasis, “Relationship between fault level and system strength in future renewable-rich power grids,” *Appl. Sci.*, vol. 13, no. 1, Art. no. 142, Dec. 2022.

[19] A. Shahmoon and Z. Zalevsky, “Electrical model for analyzing chemical kinetics, lasing and bio-chemical processes,” *Processes*, vol. 1, no. 1, pp. 12–29, May 2013.

[20] V. A. Ani, “Simulation of a sachet water processing plant using an analogous electrical model,” *Journal of Engineering and Technology Research*, vol. 5, no. 6, pp. 170–188, Jul. 2013.

[21] PJM Video: Understanding Synchrophasors. Available: https://www.youtube.com/watch?v=WiEbo62x2eQ [Accessed Jan. 30, 2025].