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Work-in-Progress: Perceived Value of Non-Electrical Engineering Students in an Engineering Circuits Course

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Abstract

The sophomore year is a critical juncture for engineering students when many experience the sophomore slump, which can include uncertainty, lack of motivation, and possible academic decline. Providing students with engaging experiences and support is critical to help mitigate these negative feelings. While focus can be placed on extra-curricular activities, methods used within courses also have lasting impacts on the student experience.

Louisiana Tech University offers six undergraduate engineering degree programs, which include Biomedical, Chemical, Civil, Cyber, Electrical, Industrial, and Mechanical Engineering. The curricula of each of these programs require all students to complete a sequence of three sophomore-level courses, which include Statics and Mechanics of Materials, Electrical Engineering and Circuits, and Thermodynamics. These courses allow students from different majors to gain an understanding and appreciation for fundamental engineering concepts and other disciplines, which will benefit them in internships, research, and their future careers.

The courses in the sequence are taught using a traditional lecture-based approach with a few labs or projects mixed throughout. The courses are managed and taught by instructors within the programs that the courses are perceived to own (e.g., Electrical Engineering and Circuits, managed by faculty in the electrical engineering department). The current approach to the courses is perceived negatively by students. Many students are not engaged in the courses, and those students who do not see it as applicable to their discipline can lack motivation while taking the course. Students often approach the course with the mindset of checking the box for their curriculum requirements. Redesigning the sequence to leverage evidence-based, engaging pedagogy could help students in all disciplines appreciate the courses and recognize the sequence's value to their education.

This work-in-progress paper focuses on the Electrical Engineering and Circuits course within the sophomore sequence by outlining updates made to the course. These adjustments were implemented in a pilot section during the 2024-2025 academic year. Testimonials from non-electrical engineers in industry were presented at the beginning of class each day to help students connect the course content with majors outside of electrical engineering and see how the course can be beneficial in their careers. In addition, problem- and project-based learning activities were added to the course.

A survey assessing the students' perceived value of the course as it relates to their major and careers was given to students in the pilot course as well as the concurrent sections that were taught in the traditional manner. The survey will provide a baseline understanding of how the initial changes integrated into the pilot section impact the students' perception of the course and its benefit to their general engineering education, their major, and their future careers as compared to the students in the traditional sections.

Introduction

Sophomore Slump

The second year for engineering students presents unique challenges where students are often met with uncertainty, lack of motivation, and academic decline. These feelings and experiences are often referred to as the "second-year or sophomore slump," which is defined by McBurnie, Campbell, and West as "a lack of engagement that can be experienced by students entering their second year at university [1]." While this phenomenon is widely recognized by institutions of higher education [2], [3], [4], [5], [6], [7], [8], there is need for empirical research on the experiences of these students and the curricular interventions that can be implemented to help mitigate the negative experiences and feelings [9]. Specifically, in the Cambridge Handbook of Engineering Education Research, Lord and Chen highlight the importance of researchers to examine the middle years of engineering education. While many engineering education efforts center around the first and senior years, the middle years are often neglected [5], [9]. It is important to recognize that the second year is a critical juncture for students where they often solidify their major choice, directly impacting their retention within a program as well as at the university [3], [5].

[9] posits that resistance to address the slump may in some ways be attributed to the instructors of the courses not wanting to change the content due to being comfortable with how the courses are, believing there is not enough time and resources to make changes, and being reluctant to remove or adjust content since the courses are typically pre-requisites to future courses. While these concerns can be valid, evidence suggests that the attrition and retention issues influenced by the sophomore slump necessitate change [3], [5]. Specifically, the National Academy of Engineers (NAE) and the American Society for Engineering Education (ASEE) are developing a framework to establish practices of "weaving students into engineering, not weeding them out (WINWO) [10]." Many practices that are foundations of weed-out culture, like "cramming too much material too quickly, heavy focus on theory with little application or context, primary reliance on a lecture with no hands-on, team-based activities or application experience" are prominent in second-year courses [10]. These course structures can cause significant second-year stressors and disengagement, thus contributing to the sophomore slump. The NAE-ASEE WINWO Framework calls for curriculum reform using robust pedagogies while emphasizing significant culture shifts in how we approach engineering education [10].

Louisiana Tech University offers seven ABET accredited, degree-awarding engineering programs, including Biomedical, Chemical, Civil, Cyber, Electrical, Industrial, and Mechanical Engineering. Students in each discipline are required to take a three-course sophomore sequence, which includes Statics and Mechanics of Materials, Electrical Engineering and Circuits, hereafter referred to as Circuits, and Thermodynamics.

In the mid-90s, Louisiana Tech established the Integrated Engineering Curriculum (IEC), including a first- and second-year sequence that integrated engineering, math, and science concepts [11]. While the first-year sequence has thrived, the sophomore sequence has struggled to maintain structure and engagement. Initially project-based, these courses have shifted to traditional lectures with fewer projects. This decline may be attributed to a lack of cross-discipline collaboration and specific disciplines taking ownership of the courses, reducing their broader applicability. This shift has led to decreased engagement from students who view the courses as mere requirements with little value to their disciplines and careers. This negative perception harms student retention and development as well-rounded engineers.

Expectancy Value Theory and Perceived Value

Expectancy-value theory (EVT) as explained by [12] suggests that expectancies and values influence achievement choices, performance, effort, and persistence, while the expectancies and values are influenced by “task-specific beliefs such as ability beliefs, the perceived difficulty of the different tasks, and individuals’ goals, self-schema, and affective memories.” This theory includes four different types of achievement values, defined by [12], which are attainment value (“the importance of doing well on a task”), intrinsic value (“the enjoyment one gains from doing a task”), utility value (“how a task fits into an individual’s future plans”), and cost (“how the decision to engage in one activity limits access to other activities”).

EVT has begun to be applied to engineering education and other STEM fields as a way to predict students’ choices, effort, persistence, and success in these fields [13], [14]. In [15], the researchers recruited first-year engineering students from a large, public university in the United States and, using a survey and academic records, determined how self-efficacy and the previously mentioned values individually and jointly predicted students’ engineering career intentions, educational aspirations, engineering retention, and GPA. The main conclusion of the study was that, although each of the predictors correlated differently with the four outcomes, there were significant interactions between self-efficacy and interest/utility values so this should be considered when creating ways to help students’ motivations. This is opposed to only supporting their self-efficacy or the values/costs individually. [14] had very similar findings in their study of EVT and self-efficacy which was assessed via a survey given to 163 engineering undergraduate students. [13] found that there was an “overlap between the students’ expectancies and values, not including costs, which predicted their end-of-term academic achievement, study program satisfaction, and course dropouts” (p 138). [16] utilized two years of student data which included ACT scores, responses to EVT surveys at the beginning and end of the semester, academic performance in first-term math, chemistry, and engineering, and retention, along with clustering analysis, principal component analysis, and decision tree classifier to complete their study. Overall, the researchers found that, like previously mentioned research, “the [EVT] framework…significantly predicts persistence” in engineering and “can also predict performance in the first math course.” They suggested the possibility of creating a model that could utilize the EVT surveys to determine which students needed early intervention to pass first-term math.

Perceived value is a marketing term defined by [17] as “the value of a product based on how much customers want or need it, rather than on its real price.” This study branches from this definition to define perceived value as the value a student places on taking Circuits and the knowledge gained from the course, rather than how beneficial instructors believe the course to be for the students. This definition relates directly to utility value as defined by EVT. [18] examined students’ perceived value of a first-year engineering course series. They noted a key lesson learned from the focus groups and surveys they implemented was “connecting technical skills with course activities and engineering content [can] provide a more meaningful experience.”

Motivation

Students have reported low satisfaction with the sophomore Circuits course. When students were asked “do you have any suggestions for improving the course,” some responses received were:

- “Civil engineering students should not have to take this course because it doesn’t [sic] not apply even in the slightest.”
- “Split course into two sections, Circuits for mechanical, electrical, and comp sci, and a circuits for Civil and chemical. I don't know about chemical engineering, but circuits feels less useful for Civil engineers to know.”
- “Remove it from the [sophomore] series.”
- “It was taught very well, I just don't think it is all that relevant to industrial engineering.”

The perceived value of Circuits is very low in the minds of many students, especially those not majoring in electrical engineering. Therefore, the focus of this work-in-progress paper is to assess the impact on the perceived value for the non-electrical engineering students in a pilot version of Circuits during Fall Quarter of the 2024-2025 academic year. The pilot section incorporated strategic components intended to increase the students’ perceived value of the course.

Overview of Circuits

As previously stated, Circuits is a part of the sophomore course series that also includes Statics and Mechanics of Materials and Thermodynamics. These courses are taken non-sequentially, with the order depending on the major. Each course meets for 110 minutes per session, three times a week and awards three semester credit hours.

The topics covered in Circuits are:

- Basic Electrical Terminology and Quantities
- Ohm’s Law
- Kirchoff’s Laws
- Resistor Combination
- Source Combination
- Current and Voltage Division
- Linearity and Superposition
- Nodal and Mesh Analysis
- Thevenin and Norton Equivalent Circuits
- Practical Sources and Source Transformations
- Inductance and Capacitance
- Transient Analysis
- Operational Amplifiers
- Phasors and Impedance
- Alternating Current (AC) Steady-State Analysis
- AC Power

These topics are covered via lectures over the 10-week quarter with 8 “minilabs” dispersed throughout the quarter. The labs do allow for hands-on experience with circuits, but they do not go further than simply proving the theory that was discussed in the lecture. For example, for voltage division, the students set up a simple voltage divider circuit and observe the voltage drop over different sized resistors. In addition to the minilabs, the students complete homework through an online portal (WeBWorK) and have the opportunity to complete In-Class Assignments (ICAs). The ICAs consist of 1-3 problems related to the day's material. These are completed collaboratively with other students at their table at the end of the lecture, allowing them to solidify their understanding and seek assistance from the instructor before leaving the classroom if needed. Three multiple choice exams are given throughout the quarter to test the knowledge of the students.

Pilot Version of Circuits

The pilot section of the Circuits course is designed to include components intended to increase the students' perceived value of the course. Some adjusted elements found in the pilot course are testimonials from practicing engineers, new projects, additional lectures, in-class demonstrations, and cross-disciplinary framing for lab assignments. Core elements of the Circuits course were kept consistent between the pilot and traditional sections to ensure a reliable basis for comparison. The classes continue to meet for 110 minutes per session, three times a week, and award three semester credit hours. Minilabs and ICAs are still conducted, and exams remain nearly identical to those in the current version, with adjustments made as needed to incorporate the new lecture material.

Engineer testimonials presented at the beginning of each class period

Testimonials were solicited from practicing non-electrical engineers addressing why they think Circuits knowledge is important and/or how they have used it in their careers despite not being an electrical engineer. One example of a testimonial presented from a chemical engineer was:

> "In 2023, I was the principal analyst of a root cause failure analysis to determine and remedy the latent causes of power distribution failures over the previous 3 years to prevent future major failures and identify opportunities for power infrastructure improvement. This required understanding electrical concepts, such as phase-to-phase faults, ground faults, the effect of voltage lag on equipment, and breaker trips on underfrequency/overcurrent. Basic knowledge of electrical principles and equipment made understanding these practical applications much easier."

Lecture and demonstration about ideal transformers

After the lectures on inductors and capacitors, a demonstration of a simple transformer is performed using a toroidal core and two pieces of wire. The students observed that two inductors wound around the core allow for transmission of power through the air. A lecture followed on the basics of ideal transformers and their uses in industry, such as transmission/distribution of AC power.

Introduction to the AC power lectures about AC power in the real world

Observations of students' comments in class showed that they dislike discussing AC power because they perceive that it differs greatly from the DC circuits they worked on earlier in the quarter and is more difficult. The addition of complex numbers and angles do not help matters. Therefore, an introduction to AC power is presented to show the importance of AC power in the real-world including things like generator basics at power plants, transmission and distribution, and AC power in our homes.

Lecture and hands-on interaction relating to a motor starter circuit

For this lecture, students are presented with a simple motor starter circuit and asked how it works. Very few, if any, are able to explain the circuit. Then each component of the circuit is discussed such as breakers and fuses, cables and their sizing, push buttons, and electromechanical relays. Various sizes of cables and a breaker are brought to class, allowing students to engage directly with the components. This hands-on interaction helps foster inquiry and deepen their understanding of the materials and concepts by providing a tangible connection to real-world applications.

Problem-based learning style prompts added to all minilabs

To maintain consistency with the non-pilot sections, the activities required through the minilabs remained the same. However, a prompt was added to each to encourage the students to think more deeply about how these situations/circuits could be encountered in industry. For the voltage divider minilab mentioned in the last section as an example, the following prompt was added:

> "You're conducting the below experiment because you have two small motors, and they seem to be getting hotter than you'd expect. You know it's not a good idea to run motors outside of their operating voltages because, if run at too low a voltage, the motor can overheat and fail. You also know from the datasheet that Motor 1, which has an internal resistance of 5.1 kOhms, needs approximately 2 V to operate, while Motor 2, which has an internal resistance of 2 kOhms, needs approximately 5 V to operate. Determine the current operating voltages of each motor using the steps below. After you complete the MiniLab, write a sentence or two suggesting where your 1 kOhm resistor should be placed so the motors can operate as close as possible to their ideal operating voltages."

Problem-based learning style operational amplifier design project

An operational amplifier design project was implemented which presented the students with a dilemma that they needed a certain shape wave to test of a piece of equipment, but their waveform generator could not produce that shape. Therefore, they are required to decide on an op amp circuit that can transform the output waveform to the shape they need then write a memo to their supervisor about their circuit and show their results on the oscilloscope.

Data Collection

Three surveys were conducted with students in the current version and pilot version of the course. A Pre-Circuits EVT and Post-Circuits EVT survey were given at the beginning of the first day of class and the end of the last day of class respectively. This survey was adapted from [15] and included 23 prompts that were answered on a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). The prompts were kept essentially the same between the two surveys except rewording as necessary from future tense to past tense. The three prompts that are used for the focus of this paper are the three related to the course's utility value as defined by EVT which directly correspond with our definition of perceived value:

1. [Circuits] is valuable because it will help me in the future.

2. [Circuits] content will be useful for me later in life.
3. Being good in [Circuits] will be important for my future (like when I get a job or for graduate school).

The third survey is an End of Course (EOC) survey that posed various questions such as:

- I believe the content in [Circuits]…
    - Is relevant to my career path.
    - Is beneficial in my development as an engineer.
    - Relates to industry applications.
- For the lecture topics listed, rate the level of value you feel each has on your future as an engineer.
- The Engineer Testimonials led me to believe that [Circuits] is more valuable for my future than I initially thought at the start of the quarter. (This question was not presented to the current version students as they did not see the engineer testimonials.)
- What did you like most/least about the course?

Results and Discussion

To analyze the Pre/Post-Circuits EVT survey responses, the responses were filtered by those in the pilot section versus the non-pilot sections of the course who were non-electrical engineering majors. This gave a sample size of 15 for the pilot section and 31 for the non-pilot sections. Note there were two non-pilot sections of the course, so their students were combined into one sample of 31.

Jamovi version 2.3 was utilized to conduct six Paired Samples T-Tests. Portions of the results can be seen in Table 1. Tests with an effect size “d” were conducted using Student’s T with Cohen’s d for the effect size. Tests with an effect size “r_{rb}” were conducted using Wilcoxon Rank with rank biserial correlation r_{rb} for the effect size due to a violation of the assumption of normality.

Table 1. EVT Survey Paired Samples T-Test Results

EVT Prompt	Class Section	Pre-Circuits Mean	Post-Circuits Mean	Mean Difference	p-value	Effect Size
1: [Circuits] is valuable because it will help me in the future.	Non-Pilot	3.29	3.19	- 0.10	0.72	d = 0.07
	Pilot	3.60	3.87	+ 0.27	0.43	r_{rb} = 0.36
2: [Circuits] content will be useful for me later in life.	Non-Pilot	3.45	3.19	- 0.26	0.35	d = 0.17
	Pilot	3.73	3.93	+ 0.20	0.57	r_{rb} = 0.33
3: Being good in [Circuits] will be important for my future (like when I get a job or for graduate school).	Non-Pilot	3.03	2.77	- 0.26	0.29	r_{rb} = 0.24
	Pilot	3.67	3.67	0.00	N/A	N/A

As seen in Table 1, none of the t-test results can be considered statistically significant. However, the pilot students’ agreeableness to the prompts either stayed the same or increased from the beginning of the quarter to the end, while the non-pilot students' agreeableness to the prompts decreased for all three.

EOC Survey

Ten non-electrical engineering students from the pilot course responded to the EOC survey. When prompted "The Engineer Testimonials led me to believe that [Circuits] is more valuable for my future than I initially thought at the start of the quarter," nine out of the ten said they either "agreed" or "strongly agreed" with the statement, with the tenth stating they already believed the course was valuable at the beginning of the quarter.

Two of the students, when asked what they liked most about the course, brought up the motor starter circuit lecture and how they appreciated seeing industry applications of circuits, breakers, and wire gauges.

Conclusion, Limitations, and Future Work

In conclusion, a pilot section of Circuits, which included testimonials from practicing engineers, new projects, additional lectures, in-class demonstrations, and cross-disciplinary framing for lab assignments, was implemented to increase the perceived value of non-electrical engineering students. While the changes were not dramatic, both the EVT and EOC survey show promising results that the students' perceived value of Circuits increased due to the changes made for the pilot course.

Limitations

As previously stated, this pilot version of Circuits was during the Fall Quarter which is when the majority of electrical engineering students take the course in order to progress in their major efficiently. Therefore, the sample size of non-electrical engineering majors was small. This was exacerbated by the fact the course has a high drop rate, with 13 dropping the pilot section alone, so these students did not take the Post-Circuits EVT survey or the EOC survey.

In addition, the responses to the EOC survey were not as large as the EVT responses, with one non-pilot section of the course having no responses at all. This is due to not giving students a chance during class to complete the EOC survey but relying on them to complete it on their own time. There was also some confusion that they had already completed the survey because the Post-Circuits EVT survey was given during class time. They did not realize there were two surveys to complete on the last day of class – the EOC survey and Post-Circuits EVT survey – despite multiple attempts to clarify via the course sections' homepage.

Future Work

Another pilot section of the course is being implemented at the time of writing (Winter Quarter) to add to the data already collected. The number of electrical engineering students in Winter Quarter's sections is less than in the fall which will allow for larger sample sizes of non-electrical engineering students. Future analysis will include the EOC survey data to compare the pilot and non-pilot section responses.

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