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# WIP: Reducing the Failure and Dropout Rate for an Introductory Circuits Course

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## Introduction

In this work-in-progress paper, we analyze how changes to our introductory circuits course decreased our dropout and failure rate in the course. Our large, western, public research university assesses departments by their "DEWI" rate, which represents D grades, E grades (called F at many other universities), Withdrawals, and Incompletes. Our introductory circuits course in electrical and computer engineering was regularly flagged as one of the highest DEWI rates in the College of Engineering with an average DEWI rate of 33% over the last eight years.

Due to pressure from the college of engineering and also desire within our department to improve student outcomes and better match the learning needs of the 21$^{st}$ century, we made significant changes to our introductory course sequence for electrical and computer engineering majors. The changes came about from weekly meetings of our undergraduate curriculum committee over the course of two summers. The committee included two faculty members who had a background in education research and two faculty members who had many years of experience teaching the entire introductory sequence.

We settled on the following changes for the introductory circuits course to try and reduce our failure and dropout rate:

1) Reduce speed of core concepts (which reduced total content in course)
2) Greater focus on higher-order skills (design and real-world applications)
3) Make more accessible through removal of calculus co-requisite
4) Move to a studio style classroom (previously was a flipped classroom with separate lab)
5) Reduce class size to 50 students

The changes were successfully implemented in the fall of 2025, and as a result we saw record low numbers of students failing and dropping out. After two terms of the new course, our average dropout rate is 13%, which is a record low and statistically significant.

## Background

This section gives a brief overview of education research related to the changes we chose to implement in our introductory circuits course.

Studio classrooms have been extensively studied in the physics education world for decades. Implementations like SCALE-UP [1], TEAL [2] and Tutorial Physics [3] have been used for years across the nation and inspired our implementation of a studio classroom. In general, it is found that students have more learning gains in a studio classroom based on pre- and post- test gains and losses as measured by concept inventory tests [4]. Others have found no significant difference in test scores between classroom types but have found increased self-efficacy and interest in physics [5]. That same group also found that girls who continued on to higher level physics classes were more likely to have self-selected to not take traditional lectures in the introductory courses, so the studio classroom may have played some role in their continuation in physics.

The move to a studio-style classroom was instigated in an effort to have more faculty support for teaching lab skills and troubleshooting circuits. Other anecdotal reasons for switching from a flipped classroom to a studio-style classroom were 1) our department felt that not all professors were using the flipped classroom effectively and 2) students' ability to study independently decreased post-COVID.

Another problem we noticed and the data supports is the decreasing math ability of our incoming students. According to the National Assessment of Educational Progress, K-12 students of all age levels have decreased math scores since COVID and the losses have not yet disappeared [6],[7]. Other universities have also found that student knowledge of prerequisite topics declined during COVID and online learning, which matches our own experiences [8].

Researchers at the University of Nebraska Lincoln interviewed faculty and staff for an introductory engineering course that had a large failure and dropout rate at their university [9]. These instructional staff indicated five core reasons students were not succeeding: 1) Large class size 2) Lack of practical applications 3) Weak prerequisites 4) Not taking advantage of class resources and 5) Inability to changes strategies based on feedback.

The research on the effect of class size is less conclusive with some groups finding gains with smaller class sizes and some finding no difference in outcomes between large and small classes.

San Jose State University has indirectly studied the effects of class-size on failure rates. They noticed that students coming out of the community college pre-req math and science classes for introductory circuits were performing much better and they suspected it was due to the smaller class sizes at the community colleges [10].

The University of Maryland looked at the effect of class size in their honors program and found no difference in outcomes between 65-person classes and 45-person classes [11]. Similarly, a faculty member at University of Florida teaching Engineering Economics looked at differences in analysis quality on final exams between small classes (<40 students) and a large lecture (150 students) and found no difference between the class sizes [12].

Physics instructors at UC Davis looked at how changing from 50 to 100-person classrooms for an introductory physics class affected students and found the size of the classroom was not the main factor in students' perceptions of the course [13]. Rather, their connection with their TAs and things like lighting and arrangement of the seating seemed to play a bigger role in student perception of the class.

While there was not a lot of evidence that reducing class size would make a difference, it was the desire of the new head of our department to create a more personable environment for new students in the major, so it was decided to put more teaching resources into our first circuits course. Therefore, we switched from 100+ size classes to 50-person classes for intro circuits.

It is difficult to know which of the five changes—speed of content, focus on design skills, reduction of math pre-requisites, use of a studio classroom, or reduction of class size—had the biggest effect on reducing DEWI rates, but all the actions together had a sizeable effect.

**Method**

The goal was to have an introductory circuits class that everyone could take their first semester at the university to capture their excitement about the major and keep them interested. To be accessible to more students, we reduced the math co-requisite from calculus to precalculus. This meant we could no longer teach capacitors and inductors in our first circuits course. Therefore, we focused the course on resistive circuits and their applications as sensor systems.

The new introductory circuits course is a combination of the former freshman seminar, the first third of the old Circuits 1, and a newly added unit on digital logic (see Fig 1). The former freshman seminar was a combination of lessons on college skills and career options along with hands-on lab activities and math review. The lessons on college skills and career options were brought into the new intro circuits along with some of the math and hands-on lab activities. We chose to cut off the learning material after resistive circuits due to the lower math requirement for the new intro course. Digital logic was added to make sure every student in the 21$^{st}$ century had exposure to these ideas, since the junior level breadth course is not required for all. Since the junior level class also has a lot of material packed in it, this earlier exposure to digital logic also helps make the junior level digital design class less overwhelming.

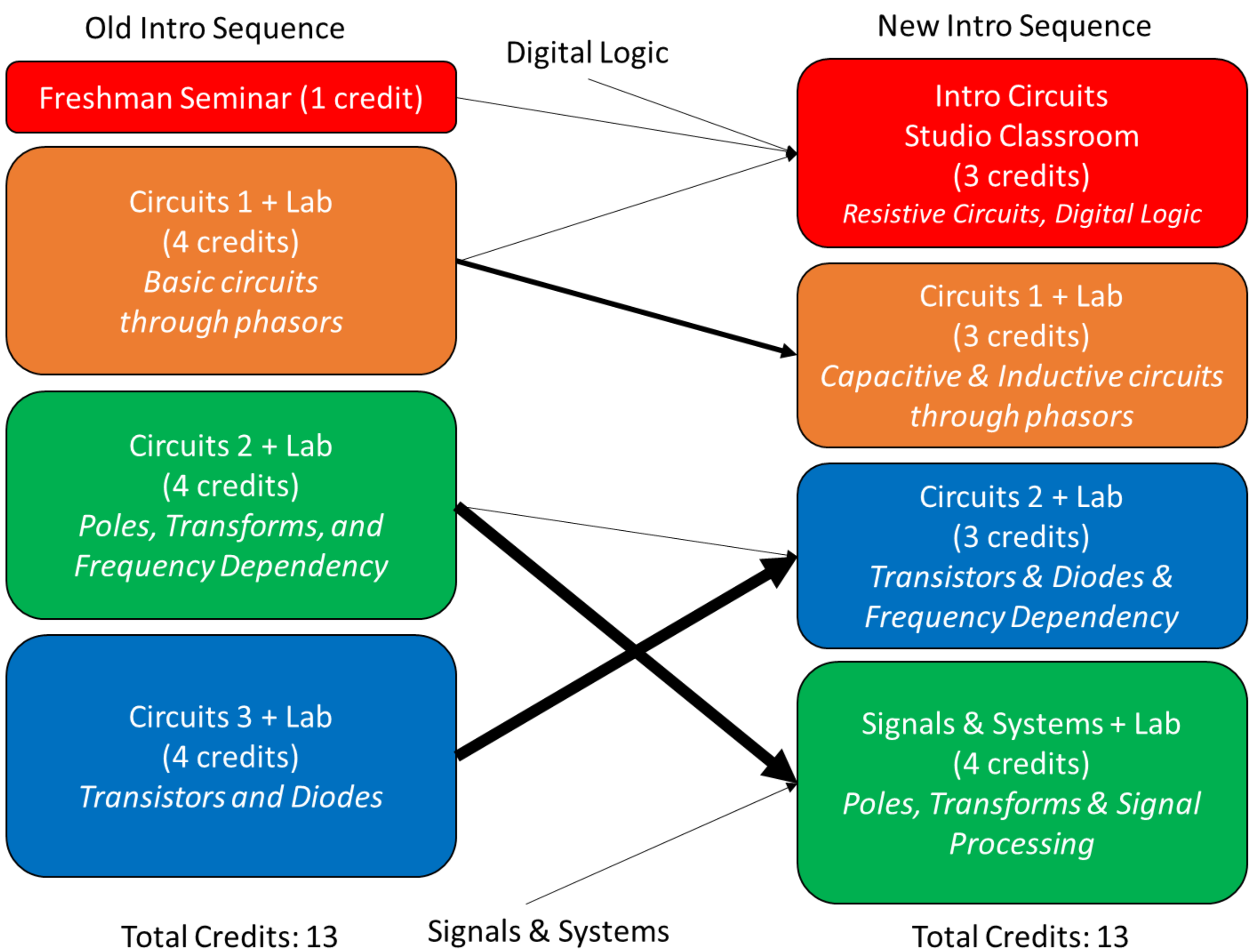


**Figure 1.** Changes to the introductory sequence.

These changes to the first circuits course are part of a larger change to our entire introductory sequence in electrical and computer engineering. The new Circuits 1 course contains the rest of the old Circuits 1 class, which includes the topics of Thevenin equivalence, superposition, op-amps, capacitors, inductors, and phasors. Circuits 1 also has a separate lab which is their first exposure to the standard electrical engineering lab space, MATLAB, and circuit simulators.

To better match the math sequence, we switched the order of the old Circuits 2 and 3 classes, since Circuits 2 required differential equations. Since there was a lot of overlap between Circuits 2 and traditional signals and systems curriculum, we decided to combine that material with our junior-level signals and systems breadth course and make it a required course.

Circuits 3 essentially stayed the same focusing on transistors and further expanding topics on frequency analysis but got renumbered Circuits 2.

Notice that we did not change the number of credit hours in the introductory sequence, rather just how the hours were distributed. To make room for digital logic and signals and systems in the introductory sequence, overlapping material between freshman seminar and Circuits 1 was removed along with overlapping material from the old Circuits 2 and Signals and Systems.

Because material was slowed down in the first two circuit courses, we were able to focus more an higher-level skills like design tasks and real-world applications. Before, in the quicker version of the class, most of the emphasis was placed on analysis and mathematical calculations, because that was all we had time for to get through all the material in time. This greater emphasis on conceptual understanding, design work, and real-world applications led to more difficult exams. Using the metrics set forth to score the difficulty level of physics problems by the physics education research group at the University of Minnesota, we can show that the difficulty score for our exam problems increased due to increased problem context and and increased length of problem statements for the real-world problems [14].

Students were split into groups of roughly 50 students, which meant that we needed to run 3 sections of intro circuits in Fall 2025, instead of a single section of 150 as we had previously run. One section was an accelerated version of the class (where they took Intro Circuits & Circuits 1 in one term) and two were standard sections of the class. Any student who received <70% on the first exam in the accelerated section was moved into the standard version of the class at the end of the first two weeks. Five students transferred this way in Fall 25 and two in Spring 26.

Along with changing the content of the courses, we also changed the delivery mode. Intro Circuits was previously a flipped-classroom with a separate lab period. We changed to a studio classroom as a way to incorporate lab work into the classroom and also to address a concern from the head of the department that 15% of students were coming to him complaining consistently term after term about the flipped format. We felt the studio classroom would give the right blend of problem-based learning and traditional lecture.

Classes were taught in normal lecture halls most terms instead of a studio classroom with group work tables, because there are very few of this special type of classroom available on campus. This traditional lecture hall had rows of tables looking down at a central lectern. We were able to use a collaborative classroom with group tables for one section the second term. Group cohesion in that term was visibly improved and students' midterm feedback indicated their favorite part of class was building circuits and being in their "learning pods" as they called their tables.

We used the old in-class homework from the flipped classroom as the basis for our in-class worksheets combined with modified versions of the old labs. We then added conceptual material based off the findings of the Tutorial Physics creators [3]. Finally, we created self-grading online homework that gave students immediate feedback. Each student got unique numbers and they could keep attempting the homework until they got the answers correct (for full credit). We also used conceptual clicker questions in lecture to engage students.

To make sure students were learning the laboratory skills, we included physical circuit-building on exams. Originally, we were planning on giving them scores on circuit-building through their daily class worksheets, but some students were copying neighbors' measurements or a few were even plagiarizing results. As a result, we decided to move to a system where students were tested on their lab skills. Exams 2 and 4 included a circuit-building problem (one quarter of the exam) where students built a small circuit in real-time during the test and took a current or voltage measurement. They showed the professor the circuit in real-time and received stamp marks for correct work (partial credit was possible).

The grading breakdown did not change significantly between the old and new versions of Intro Circuits. We use a mastery-based system where 80% of the class grade is based on 4 midterm exams. There is no final exam, but rather the final exam period is a time when students can take a new version of the midterm exams to improve their scores.

**Results**

After two terms of data, we were already able to show a statistically significant decrease in DEWI rate for the new introductory course via an unpaired t-test ($p=0.0054$). We compared the new intro course DEWI rates against the historic version of the course from Spring 2017 to Spring 2024. The new course has an average DEWI rate of 13% whereas the old version of the course had an average DEWI rate of 33% (see Figure 2).

We also looked to see what, if anything, was having an effect on the DEWI rate term-to-term historically to know if our results were truly comparable. We did not see any general upward or downward trends in DEWI rates over time. While we saw slightly higher failure and dropout rates during COVID, it was not statistically significant.

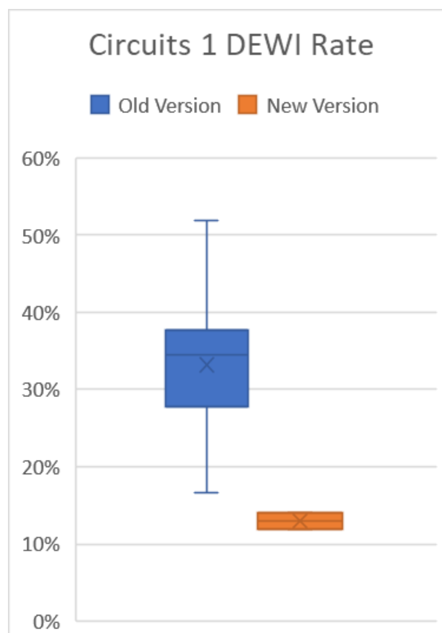


**Figure 2.** Box-and-whisker plots comparing semester-by-semester DEWI rates from 2017-2026.

We also looked at term-to-term and faculty member variance in the failure and dropout rates. Over the 7.5 years analyzed, there were 6 different faculty who taught Circuits 1 (4 female and 2 male). Four of the faculty only taught the class one or two times and the other two faculty taught the class at least 5 times each. The highest and lowest DEWI rates (52% and 17% respectively) were both for different faculty members who only taught the class once or twice.

While DEWI rates did vary greatly from faculty member to faculty member, there was also large variance in DEWI rates term-to-term for individual faculty members. For the two faculty members who taught Circuits 1 at least 5 times between 2017 and 2024, their DEWI rates ranged from 34%-42% for one and from 23-38% for the other. This shows that even when the faculty member is held constant, there is significant variance in dropout and failure rates depending on the cohort of students.

Despite record numbers of students enrolled in our new version of Intro Circuits in Fall 2025 (178 students), our DEWI rate was the lowest on record at 12%. Again, in Spring 2026 with a cohort of 77 students, we had a similarly low DEWI rate of 14%.

**Discussion**

We did not expect to get below 10% failure and dropout rate because a few students will always not successfully complete a course due to personal circumstances unrelated to the class. This portion of students is not a reflection on how the course is run, but rather external factors. Because this new DEWI rate is in line with the DEWI rate for other intro classes in the college of engineering, we feel this change to the introductory sequence has been a success.

It is hard to piece apart which of the specific changes helped with the decreased DEWI rates and which had no effect. This is one of the limitations of the analysis, but we do have a few clues related to class size and instructor variance.

While professor variance may have some effect on the DEWI rate, we do not believe that played a significant role in our outcomes. The two standard sections were run by a faculty member who had previously taught the intro course with a nearly average DEWI rate of 34%. While the professor who taught the accelerated version was the faculty member who previously had the record low 17% DEWI rate, she was also teaching the accelerated version where we expected most students to pass the course anyway (and struggling students were sent to the standard version after two weeks). Therefore, we believe that faculty variance did not play a role in the improved failure and dropout rate of the new sequence.

Due to misestimation of student enrollment numbers, we ended up with 3 sections of more than 50 students each in Fall 25 term and with 2 sections of 25 students in Spring 26 term. We did not see a rise in DEWI rates with the larger class sizes (if anything the trend went the other direction), so there is no evidence that 50-person classes versus 25-person classes adversely affects the DEWI rate. Therefore, we see no reason to have classes smaller than 50 students in future terms.

We also wondered what role moving students from accelerated to standard sections had on student success. In the old version of the class (based on numbers from Fall 23), we found that

73% of students who did not pass the first exam ended up not passing the class or dropping out. With the new intro course, we had five students not pass the first exam in the accelerated section in Fall 25 and 2 students not pass the first exam in accelerated section in Spring 26, but all 7 ended up passing in the standard section. While the group of students who chose to sign up for accelerated may be different than the full cohort in Fall 23, we would not have expected all 7 to have passed based on historic numbers—we would have expected 5 of them to have failed or dropped out based on historic data. This may be an indicator that the slower pacing at the beginning is helping some students, but we plan to keep the accelerated version to keep higher-achieving students engaged in their learning.

We will continue to follow this year's cohort of students and make sure we do not have high dropout and failure rates anywhere along the introductory sequence. We will also watch to make sure that future cohorts continue to have a DEWI rate in the low teens.

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