A Flipped First-Year Digital Circuits Course for Engineering and Technology Students

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Abstract—This paper describes a flipped and improved first-year digital circuits (DC) course that incorporates several active learning strategies. With the primary objective of increasing student interest and learning, an integrated instructional design framework is proposed to provide first-year engineering and technology students with practical knowledge of DC. The research presented here compares the effectiveness of the flipped course to the previous traditional course through a controlled experimental study. The improved effectiveness of the flipped course is confirmed through the significant increase in course content and significant improvements in students’ performance and their perceptions of their learning experience. Preliminary results suggest that students’ academic success, and their engagement and interest in engineering, can be enhanced by refinement of an integrated instructional design framework. The authors believe that this positive outcome is a result of alignment of online preview of lectures, face-to-face student/instructor and peer interactions, discussions, hands-on activities, combined with several active learning strategies infused into the class.

Index Terms—Active learning, digital circuits, engineering and technology, flipped classroom, student learning.

I. INTRODUCTION

MEETING the challenges of preparing future engineers for an ever-changing engineering context in an ever-changing world has never been greater. Unprecedented progress in electronics and programmable devices has allowed engineers from all disciplines to accomplish tasks faster and more easily. Accordingly, most engineering programs require their students to take at least one electrical engineering (EE) course [1]. Some non-EE majors, however, only see the relevance of EE to chosen area of study when they face a real-world problem, often on the job after graduation; at this point, though, their opportunity to learn applicable, real-world skills or concepts in a course-based setting has passed. Thus, one significant challenge engineering educators face is engaging all engineering and technology (ET) students in meaningful EE activities that would encourage them to persist and pursue a career in ET. In response to these challenges and opportunities, a flipped first-year (FY) digital circuits (DC) course for all ET majors is proposed, to teach digital circuit fundamentals, computer concepts, and the advanced skills and tools used in the profession.

Historically, incoming ET students must take a series of mathematics and other courses to acquire the knowledge and skills necessary for them to be able complete a meaningful ET project. The consequent long delay between their entering an ET program and having the opportunity to apply content knowledge to a meaningful technical project has a negative impact on their enthusiasm, motivation, and retention in the program [2]. Addressing this challenge, several engineering educators have updated their curricula so as to engage students in hands-on design projects in the FY curriculum. While this method potentially keeps students motivated, finding a project that FY students can successfully complete is often difficult, due to their limited engineering knowledge and skills. The DC course requires transferable skills such as critical thinking and problem solving, but not advanced knowledge in calculus.

This paper is organized as follows. Section II presents the theoretical foundation of the course design and related previous work. Section III presents the implementation of the traditional course (TC) and flipped course (FC) format, and Section IV presents the evaluation of the FC. Section V discusses the findings, and Section VI draws conclusions.

II. PREVIOUS WORK

One teaching method that increases opportunities for integrating active learning activities is the flipped or inverted classroom. In brief, this educational technique has two parts: interactive group learning activities inside the classroom, and technology-based independent learning activities outside the classroom [3]. Emerging research indicates that students in a flipped classroom become more aware of their learning, make connections to course content, and improve their learning [4]–[12]. A research survey by Bishop and Verleger [3] provides an extensive literature review of FCs, while demonstrating that there is a lack of evidence about FCs in FY ET curricula. In a study of an upper-division FC engineering course, researchers reported that instructors were able to cover more course content and implement active, problem-based learning activities in the classroom without sacrificing course content [7]. Equally important, students reported more innovation in the classroom when they had the opportunity to apply what they had learned [4]. This FC framework provides an opportunity for instructors to offer a variety of learning experiences, provide timely feedback on the
learning process, create a positive student–faculty relationship, and thus promote student success.

Historically, DC and DC theory have been taught to electrical and computer engineering (ECE) students late in the engineering curriculum [13]–[15]. An early exposure to these discrete mathematics-based engineering concepts could promote a better understanding of fundamental computer science and engineering concepts [15]. Identifying this opportunity, some institutions have offered DC in the FY engineering curriculum [16]–[18] and reported positive student outcomes such as deeper insight into the functioning of electrical and computer systems and increased self-confidence [16], [17]. This work was just with ECE students. The University of Houston has recently started offering an introductory DC course to all engineering majors, but its enrollment is limited to honor students, and it does not effectively relate DC and real-world applications [2].

In an era of digital systems, with microprocessors having crossed the benchmark of three billion transistors in a single chip [19] and hundreds of microcontrollers being embedded in a single automobile, ET students need to be exposed to microcontrollers, sensors, actuators, and their respective applications through programming. Using a computer or microcontroller as a device to control physical events is typically encountered in upper-level engineering courses [20]. The ET curriculum should change the context in which programming is taught, moving it early in the program with less focus on syntax and notation, and more on demonstrating the relation between a program statement and its impact on controlling the environment for a real-world application.

III. COURSE IMPLEMENTATION

The DC course was evaluated by comparing two fall semester offerings, the first following the TC format, and the second the FC format. Per the open enrollment policy of the university, no specific recruitment strategy was used in either semester. A three-credit course for FY ET students, it met twice a week for 75 min over the 16-week semester, with the same instructor, textbook, syllabus, and similar homework and exams. The exams were conducted at approximately the same time during the semester. The student learning objectives (SLOs) were that upon successful completion of the DC course, students should be able to do the following:

SLO-1) Convert a number between different number systems.
SLO-2) Perform arithmetic operations using binary, octal, and hexadecimal numbers.
SLO-3) Describe the operation of logic gates.
SLO-4) Perform gate-level minimization.
SLO-5) Design and optimize simple combinational and synchronous sequential logic circuits.
SLO-6) Identify current and future applications of digital circuits.
SLO-7) Implement digital circuits using electrical laboratory procedures.
SLO-8) Understand the basics of digital systems, sensors, and actuators and the relationships between them, through practical applications.
SLO-9) Control digital systems using basic programming structures such as loops, conditionals, and functions.
SLO-10) Demonstrate critical thinking and problem-solving skills in team-based hands-on engineering activities.

The traditional course only comprised SLOs 1–6; SLOs 7–10 were added when the course was flipped.

A. Traditional Course

For the first year, the DC course was taught in the TC format to a class of 24 FY ET students (22 males and two females), that served as the control group. In each 75-min class session, the instructor taught concepts using PowerPoint slides, solving problems on a white board, while students took notes. Occasionally, students were asked to solve problems on their own, with the instructor walking around the classroom to monitor student progress and provide individual feedback. Most problems solved during class were drawn from the textbook, which students were encouraged to read periodically. Hands-on activities on the course concepts were introduced in a subsequent course.

B. Flipped Course

In the second year, the DC course was taught with an FC format to a class of 17 FY ET students (15 males and two females), that served as the experimental group. All in-class activities incorporated several active and collaborative learning strategies, and all student activities incorporated critical thinking strategies. All activities were integrated to form a closed-loop system as in Fig. 1, to strengthen their alignment with the SLOs and assessment, as in the methods proposed by Dal [8] and recommended by Fink [21].

1) Pre-Class Activities: To encourage self-directed learning and ensure adequate class time for active discussion, prior to attending each class, students were required to watch two or three videos [one or two class previews and one Technology, Entertainment, Design (TED) talk each week] [22]. These class previews (audio recording of the instructor and video recording of the computer screen that has shown problem solving using a bamboo pad) served as the primary means of disseminating course material [7], and introduced concepts through schematics, equations, and tables, to engage ET students who are typically visual learners [23]. Upon completion, students were required to take a short pre-class quiz whose scores allowed the instructor to identify their understanding of concepts, for effective use of class time for active discussion and deeper synthesis of concepts.

2) In-Class Activities: The diverse nature of in-class activities requires meticulous planning of the 75 min of class time to promote active learning through discussions, demonstrations, reflection, and collaborative learning activities. Students must give continuous attention, often challenging to achieve in an FY ET class.

The first 10 min of each class session were spent reflecting on new knowledge gained from the TED talk, including but not limited to applications of circuits and systems, transistors, flapping-wing aerial robots, open- and closed-loop control systems,
autonomous self-driving cars, nano-quadrotors, miniature energy harvesters, and self-aware robots. The ET courses treating the concepts behind each of these topics were identified for the students’ various curricula. For example, one of the TED talks, “My seven species of robot” [24], was used to introduce the different types of robots, their applications, challenges in their design, and the various components used (such as logic gates, obstacle detection, pressure and light sensors, actuators and microcontrollers). This talk helped students understand that a microcontroller could be used to capture signals from a sensor, perform logic operations on the data obtained, and activate a motor or perform a similar task. Students were able to use this knowledge when they subsequently designed a temperature and humidity monitoring system, and then, later in the semester, a security system. Furthermore, this TED talk introduced EE students to the fundamental difference between an open- and closed-loop system and introduced ME students to fundamental concepts in kinematics and showed how they can help in solving real-time problems. These discussions “broke the ice” in each class, highlighted the significance of the material covered, increased awareness of ET career opportunities, and reinforced student critical-thinking skills.

The next 5 min were used to reflect on concepts learned during the previous class session. This made an effective bridge to learning new topics and aided knowledge retention [25]. The next 50–55 min of the class were used to engage students in active learning through individual and group problem solving, demonstrations, and hands-on activities. The problems solved during these sessions varied from simple algebraic equations to designing finite-state machines for a real-world scenario. The open-ended nature of real-world scenario problems often required students to draw on what they had learned previously, combine this with the new concepts being learned, and thus reinforce their conceptual knowledge. The last 5 min of each class session were used for an active learning strategy that had students reflect on that day’s learning, choosing three key points plus one point that they felt required further clarification; this was revisited in the following class session. These key points were compiled each week and provided to students to serve as a guide in preparing for midterm and final examinations.

3) Post-Class Activities: After each class session, students took a post-class quiz and were assessed on their conceptual knowledge. These quizzes proved to be timely and beneficial as students were able to obtain instant feedback, and the instructor was able to assess student learning before the next session. The analytics provided by Blackboard (learning management system used for documentation, tracking, reporting, and delivery of course content) helped the instructor evaluate student efforts and learning, identify difficult concepts, and then provide timely feedback during the next session. This systematic closed-loop educational process helped the instructor use classroom time more effectively, teach more concepts, and more actively engage and maintain student interest throughout the class.

4) Increasing Student Engagement With Active Learning Strategies: Given the significance of collaborative learning for higher retention in ET programs [26], all student activities were designed to foster collaborative learning. With the FY ET students being new to collaborative learning, it was introduced through a workshop facilitated by a Teaching and Learning Consultant (TLC) from the university’s teaching and learning center. Second, all design activities were developed with an emphasis on collaborative learning and real-world applications to build upon previous design activity and to have the potential to expand for future design activity.

To introduce the concept of design and verification, the first lab activity was designed to engage students in circuit simulation. Students were required to design, simulate, and verify the logic circuit for a car seat-belt warning system using a Logisim circuit simulator [27]. With this preliminary understanding, the second lab activity taught them to read integrated circuit (IC) datasheets, operate the circuit testing equipment, and verify circuit operation on a breadboard. Students were provided with a prewired circuit of a car seat-belt warning system and were taught to read the datasheets and identify pin configuration. From the breadboard, they had to draw the circuit diagram. They also generated test patterns and used test equipment to validate the circuit functionality. This combination of circuit simulation, followed by testing a prebuilt circuit, built student confidence.

The third lab activity focused on teaching students to build a circuit, analyze its transient properties, and recognize the difference between theoretical and practical outcomes. During this activity, students were asked to design and implement a circuit for a railyard switch that determines which input track connects to the single output track per the switch’s control level.
(multiplexer). Students started by designing the circuit on paper, reading the datasheets to identify transient properties, identifying the worst-case delay path, and calculating the theoretical maximum operating frequency. They then built the logic circuit on a breadboard, tested it for all input patterns, and measured the worst-case delay to identify the maximum operating frequency. Building upon this principle of incremental learning, the next two labs required students to design a lawn sprinkler controller circuit (logic decoder) and automated lawn sprinkler system (finite-state machine with decoder and flip-flops).

The sixth lab activity required students to design and implement a temperature and humidity monitoring system for a pathogen handling facility using a microcontroller, sensors, and actuators. Students were provided with the theoretical foundation, hardware components, circuit diagram, and a skeleton program. Later, they were taught how to build a temperature monitoring system and update it to monitor temperature and humidity at various periodic intervals. This activity taught interfacing of sensors with a microcontroller and the relationships between programming constructs such as while loops, delay statements, and frequency of operation. The seventh lab activity focused on upgrading the previous system to include unauthorized entry detection and alarm capability. During this lab, students learned the principles behind operation of an infrared sensor, audio speaker, and programming constructors such as variables, user-defined functions, and fundamental numerical analysis.

The last lab activity was designed to demonstrate how to integrate various circuit elements such as logic gates, resistors, LEDs, a microcontroller, an ultrasonic sensor, a servomotor, and a miniature speaker to solve a problem that emulates a real-world scenario, that of designing an automated national security system with the following criteria.

1) Hide the weapon system when no intruder is detected.
2) Inform key personnel when an unauthorized entry is detected within a distance of 1 m.
3) Engage the weapon system upon authorization from three key personnel and presence of unauthorized entry.
4) Vary alarm intensity with respect to distance of intruder.
5) Use only two analog pins of the microcontroller (apart from the power supply pins) to verify criterion 2.
6) Use only two output pins (apart from the power supply pins) to engage the missile system and alarm.

This lab activity taught students the integration of various systems, the basics of analog-to-digital conversion through calibration of an ultrasonic sensor, digital-to-analog conversion to play a tune on a speaker, the relationship between program constructs and their respective impact on controlling the environment, and interfacing logic gates with a microcontroller.

IV. EVALUATION

Since students were randomly assigned to the TC and FC, it was important to establish the comparability of the experimental and control student populations on the available aptitude variables such as the composite ACT score and their high-school grade point average (GPA). Descriptive statistics were compiled for both course offerings; see Table I. The mean and standard deviation for both metrics are similar in the TC and FC student populations, validating their comparability.

One of the significant outcomes from the FC was the number of SLOs achieved when compared to the TC. This was not due to students spending more time on the work, as according to student self-reporting. Effectiveness of the FC was evaluated by comparing the content coverage, exam performance, and student perception of teaching, learning, and instructional methods. In addition, as the core SLOs for TC and FC were the same (SLOs 1–6), and the exams were written to be as similarly as possible, the course was assessed based on student performance, with a strategy similar to that presented in [9]. All the exams were constructed using multiple-choice, true-or-false questions that aligned with prior problems solved during the pre- and post-class quizzes, short-answer questions, and circuit design questions solved during in-class activities, in alignment with the SLOs.

One of the primary objectives of the FC was to teach the TC content more effectively, and in less time, so as to be able to introduce new concepts into the course. By flipping the course delivery format and introducing numerous active learning strategies, the 15-week course content from TC was covered in 10 weeks, providing additional time for further design activities. Midterm and final examination grades were analyzed to evaluate the impact of the FC; see Table II. Not only did the mean student grade increase, but also the standard deviation decreased in all exams. It is also noteworthy that distribution range between the minimum and maximum grade reduced significantly in FC. Furthermore, the grade distribution in Fig. 2 shows that the number of A/A+–B+ grades increased at the cost of B/B−/C+, and the number of C−/D+ grades

### Table I

<table>
<thead>
<tr>
<th>Group</th>
<th>Traditional Class</th>
<th>Flipped Class</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-school GPA</td>
<td>3.02 (0.87)</td>
<td>2.97 (1.14)</td>
<td>-0.05</td>
</tr>
<tr>
<td>Composite ACT</td>
<td>23.14 (2.66)</td>
<td>23.63 (4.67)</td>
<td>0.49</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC: Midterm-01</td>
<td>77.86</td>
<td>13.88</td>
<td>38.00</td>
<td>95.00</td>
</tr>
<tr>
<td>FC: Midterm-01</td>
<td>88.33</td>
<td>8.55</td>
<td>70.00</td>
<td>97.00</td>
</tr>
<tr>
<td>TC: Midterm-02</td>
<td>84.04</td>
<td>13.93</td>
<td>53.00</td>
<td>100.0</td>
</tr>
<tr>
<td>FC: Midterm-02</td>
<td>95.37</td>
<td>6.62</td>
<td>82.00</td>
<td>100.0</td>
</tr>
<tr>
<td>TC: Final</td>
<td>78.63</td>
<td>11.68</td>
<td>55.00</td>
<td>97.00</td>
</tr>
<tr>
<td>FC: Final</td>
<td>83.68</td>
<td>9.75</td>
<td>65.00</td>
<td>100.0</td>
</tr>
<tr>
<td>TC: Overall</td>
<td>79.72</td>
<td>12.63</td>
<td>44.98</td>
<td>91.63</td>
</tr>
<tr>
<td>FC: Overall</td>
<td>87.22</td>
<td>8.28</td>
<td>67.83</td>
<td>95.82</td>
</tr>
</tbody>
</table>
increased at the cost of E grades, further demonstrating the promising impact of the FC.

To analyze the statistical difference between the two course formats, statistical procedures were followed as in [14]. Statistical distribution of the grades from both courses were assumed to follow normal distribution under visual inspection. The Levene statistic, the commonly used test to verify homogeneity of variances for normal distribution, was performed. The $p = 0.00$, and $p = 0.04$ values, shown in Table III, show that the hypothesis on the homogeneity of variances is valid for midterm-02 and the overall grade. Furthermore, one-way ANOVA analysis was performed at the 0.05 significance level as presented in Table IV. Results obtained with $p = 0.04$ demonstrated that there is a statistical difference between the TC and FC formats, with statistically significant improvements in FC. These findings are consistent or better than those reported in other research studies [7], [8], [10]–[12].

To further evaluate the effectiveness of the FC, student performance on similar problems in the TC and FC was compared and grouped by SLOs; see Table V. While there is no significant difference in mean scores for SLO-1 and SLO-2, students in FC performed better for SLOs 3–6. The FC allowed for reinforcement of concepts through hands-on activities, with an emphasis on students identifying diverse applications of each concept. Accordingly, in addition to being able to solve problems as in TC, FC students were able to reinforce their critical thinking and problem-solving skills in a collaborative environment, as evident through better mean scores in SLOs 3–6. The mean scores for SLOs 7–10 in FC demonstrate that students were able to identify applications of DCs, implement them using electrical laboratory procedures, and to interface logic gates with microcontrollers, sensors, and actuators. Student responses to questions on applications of DC concepts, shown in Table VI, and reflections of their learning, shown in Table VII, demonstrate that they had a good understanding of the underlying DC concepts and an ability to solve simulated real-world problems, and that the course had reinforced their critical thinking and problem-solving skills. It is the instructor’s belief that the diverse instructional methods combined with prompt student feedback helped to achieve this improved student performance.

In addition, the TLC performed qualitative evaluation throughout the semester. During first day of class, the TLC conducted a workshop on collaborative learning and introduced students to the various forms of learning, presented learning strategies, and set a path for students to follow through the semester. A mid-semester feedback session was conducted.
during the sixth week and was instrumental in evaluating how learning was occurring and what could be done for further improvement. Responses from this feedback session were summarized with recommendations on instructional practices; this is shown in Table VIII, where the first column corresponds with the following prompt provided on a worksheet to each student feedback group: “List the major strengths of the course that are helping you to learn,” and the second column corresponds to the student feedback as provided for the statement, “Please explain briefly or give an example for each strength.”

In addition, a six-statement survey as presented in Table IX was given during mid-semester visit and at end of the semester, using a Likert scale of 1–5 (1—strongly disagree, 5—strongly agree). Although this survey revealed that not all students agreed that pre-class quizzes helped prepare them to learn course content, this is not a major concern since the pre-class videos were designed to provide a preview of class material, not replace it. Later as students realized that the instructor was using the pre-class quiz scores to evaluate student performance and better utilize classroom time, students took the pre-class quiz seriously and paid attention to pre-class videos through the semester. In addition, at end of the semester, students were asked to provide their perceptions on other aspects of the course learning environment; see Table X.

These statements were shaped to evaluate how changes in the course’s instructional design influenced students’ learning success. Based on student responses, 100% stated that they “would enroll in a higher-level ET class that is taught similarly,” and 72.7% responded that “because of completing this course, [their] interest in pursuing a degree in computer or electrical engineering has increased.”
Additionally, the collaborative activities provided opportunities for enhanced critical thinking and problem-solving skills essential in engineering [23]. These responses suggest that by the instructor examining the situational factors and ensuring alignment of the instructional design strategies, students were able to demonstrate achievement of learning goals. Next, the primary goal of effectively combining the technological knowledge and pedagogical knowledge to efficiently deliver course content has been achieved as stated by the students. Student responses confirm achievement of the SLOs and the effective use of active learning strategies and suggest a good potential for retention and persistence in ET. The collaborative learning strategies improved their confidence in interpersonal skills and ability to extrapolate theoretical concepts and served to ensure alignment between SLOs and course assessment.

V. DISCUSSION

Overall, the results of the proposed FC were encouraging and offered promising results in the FY ET curriculum. These results are particularly relevant, given the previous lack of evidence of successful FCs in FY ET courses [3], [7], as opposed to sophomore–senior-level courses.

While the diverse range of in-class activities increased in the FC, the amount of time the instructor spent with each individual student stayed the same. The additional time provided by the FC framework was used to introduce several individual and team-based hands-on activities to help students realize the significance and applications of DC from various perspectives and to reinforce their content knowledge. Through the numerous hands-on activities and active classroom discussions, students became better prepared to identify the significance and practical applications of ICs, microcontrollers, actuators, and sensors and were encouraged to pursue a degree in ECE. These findings combined with student responses from midterm, semester feedback and end-of-semester surveys suggest an effective alignment of teaching and learning activities with the student learning objectives, feedback, and assessment strategies.

In addition to conducting a mid-semester evaluation, the TLC collaborated with the instructor outside the class to provide advice on teaching and learning practices, to review course materials and progress on course enhancements, and to provide guidance on how to address any student concerns. The TLC had the experience and professional judgment to quickly direct the instructor to specific teaching practices and to avoid overwhelming the instructor with too much information [28]. The TLC was instrumental in assisting the instructor with the difficult but essential move from data to methods to improve the instructional strategies. Apart from their interaction with the TLC during the first day of class for the collaborative learning workshop, and the mid-semester feedback session, students did not realize the extent of TLCs’ involvement in the class, so this could not have biased their opinion.

When the DC course was offered in the TC format, it was often found that several students did not submit homework and/or engage in classroom discussions and lost motivation. This typically resulted in two or three students receiving E grades. When the DC course was offered in FC format, the traditional homework was updated to pre- and post-quizzes, and students were able to solve the problems and obtain instant feedback on their work. Almost every student did complete their pre-/post-class quizzes, actively participated in team activities, engaged in classroom discussions, demonstrated an interest in ET through reflections on learning, and performed better in exams compared to their peers in other sections. These reflections, along with their perceptions and exam grades, clearly demonstrate that an FC could increase student academic success, engagement, and interest in engineering.

One important difference in student responses was observed when asked about accessibility of the instructor, his/her preparedness, and enthusiasm about the subject. In a TC, while the instructor put in the effort to meet all the criteria and sought student feedback through the semester, students rarely provided any. Involving the TLC and conducting a mid-semester feedback session allowed successful instructional strategies and to be identified and updated promptly. This led students to realize that the instructor did value their learning, and as a result they approached the instructor more often and participated in numerous discussions outside the classroom. In addition, students perceived the instructor’s enthusiasm to be higher than in a TC, which is aligned with increasing student engagement.

Previous research [7], [8] stated that FY students do not have the academic maturity to succeed in an FC setting. While this was true during the first few weeks of the semester, a combination of good study skills, reinforcement of concepts through hands-on activities, and timely feedback from the instructor definitely did help the FY students succeed in the FC. Overall, students in an FC setting seem to be more aware of their learning process than students in the TC.

The diverse range of activities required the instructor to move at a swift pace, which sometimes was a challenge due to lack of preparation of some students. This meant that the instructor had to provide extra assistance during the learning activities. This would become a greater challenge when offering an FY class to more than 40 students, as a single instructor might be limited in time to interact with each student. However, it is worth exploring the possibility of teaching a flipped FY course with large student enrollment, as findings could be used to transform the first-year ET curriculum. Also, since much of the engineering curriculum is based on calculus, it would be valuable to explore introducing a similar active learning just-in-time first-year engineering mathematics class.

In the FC, it was found that the combination of pre-lecture videos, in-class discussions, and hands-on activities provided a deeper synthesis of concepts. Accordingly, with the declining costs of basic digital systems (microcontrollers, sensors, and actuators), it is worth exploring the option of requiring students to perform preliminary hands-on activities outside class followed by an in-depth exploration during class. Overall, the FC framework proved to be very efficient in bringing the students together to work on common goals and improved their knowledge in the FY ET curriculum.

VI. CONCLUSION

This paper has shared the experiences and observations of transforming an FY undergraduate engineering curriculum. Leveraging an integrated instructional framework and using
several pedagogical methods and technology tools, an FY DC course was flipped. Student performance and instructor perceptions were compared to the same course offered in the traditional format, with promising results.

Not only did the FC allow more course content to be covered, but it also helped students learn more efficiently. The proposed method enabled students to identify the applications of DC, perform logic circuit simulations, and conduct experiments firsthand. As a result, they had a better grasp of the subject and the significance of DC. Students found the proposed FC very attractive, as they were quickly able to see the benefits in their learning, and were better prepared for future courses in ET.

Overall, this research contributes to the literature by filling existing gaps in engineering education by providing an FC framework for FY ET courses.

REFERENCES

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