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How a Flexible Classroom Affords Active Learning in Electrical Engineering

Aaron W. Johnson, Max W. Blackburn, Magel P. Su, and Cynthia J. Finelli, *Senior Member, IEEE*

***Abstract*—*Contribution:* This paper presents evidence demonstrating ways in which flexible classrooms (which have movable tables and chairs that can be rearranged into different layouts) afford active learning. It highlights the quantitative increase in active learning that occurs for one instructor and discusses how the affordances of the flexible classroom support qualitatively better instructor-student and student-peer interaction during active learning.**

***Background:* Research has shown that students benefit from active learning, but instructors still perceive many barriers to implementing it. Flexible classrooms may reduce some of these barriers, and their affordances may promote better student engagement and allow instructors to use more active learning than traditional lecture-style classrooms do.**

***Research Questions:* What are the differences in the amount of active learning used by an instructor between flexible classrooms and traditional classrooms? How do instructors and students use the affordances of flexible classrooms during active learning?**

***Methodology:* An instructor at a large Midwestern university taught the course *Introduction to Electronics Circuits* in a traditional classroom one semester and in a flexible classroom the next. The two research questions were addressed through complementary quantitative and qualitative analyses of video data, classroom observations, and instructor interviews to detail the amount of active learning and the way the instructor facilitated it in the flexible classroom.**

***Findings:* The time the instructor devoted to active learning increased in the flexible classroom, while the time she devoted to instructor-led examples decreased. The affordances of the flexible classroom also encouraged more frequent and better student-instructor and student-peer interaction.**

***Index Terms*—Active learning, classroom, faculty, instruction, interaction, student.**

I. Introduction

THE BENEFITS of "active learning"—engaging students actively in their learning, going beyond having them simply take notes—have been convincingly demonstrated; students' conceptual understanding, problem-solving ability, knowledge retention, engagement, attitudes towards learning, and persistence have all been shown to increase when instructors use active learning [1]–[5]. However, despite copious research on the benefits of active learning, many barriers to implementing it remain. These barriers include concerns about the efficacy of active learning, insufficient training in implementing active learning, lack of rewards and incentives, fear of student resistance or negative student evaluations, increased preparation and class time, and constraints of the physical classroom [6]–[12]. Other research has identified strategies for overcoming some of these barriers, such as clearly explaining the purpose of the activity, providing students with regular feedback, and soliciting and acting on student feedback about the activities [13]. Furthermore, instructors who are working to implement active learning can find support from freely-available online resources with practical examples of active learning techniques [14], [15] or from faculty professional developers who have designed and led learning communities [16]–[19].

Flexible classrooms, which have movable tables and chairs that can be easily rearranged into different layouts (such as front-facing rows or small groups), are one solution to the barrier of physical classroom constraints [20]. The affordances of a flexible classroom—the movable furniture, and other technologies such as movable whiteboards and wall-mounted monitors—may support more active learning, and better instructor and student engagement in active learning. The research presented here addresses two research questions regarding flexible classrooms:

RQ1. What are the differences in the amount of active learning used by an instructor between flexible classrooms and traditional classrooms?

RQ2. How do instructors and students use the affordances of flexible classrooms during active learning?

The first research question (RQ1) is addressed through quantitative analyses of 72 lecture sessions from two semesters of a particular *Introduction to Electronic Circuits* course—one taught in a traditional classroom and one in a flexible

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A. W. Johnson is with the Engineering Education Research Program, University of Michigan, Ann Arbor, MI 48109 USA, and also with the Aerospace Engineering, University of Michigan, Ann Arbor, MI 48109 USA (e-mail: aaronwj@umich.edu).

M. W. Blackburn is with the Electrical Engineering and Computer Science Department, University of Michigan, Ann Arbor, MI 48109 USA (e-mail: mblackb@umich.edu).

M. P. Su was with the Materials Science and Engineering Department, University of Michigan, Ann Arbor, MI 48109 USA. He is now with the Department of Applied Physics and Materials Science, California Institute of Technology, Pasadena, CA 91125 USA (e-mail: magelsu@umich.edu).

C. J. Finelli is with the Electrical Engineering and Computer Science Department, University of Michigan, Ann Arbor, MI 48109 USA, also with the School of Education, University of Michigan, Ann Arbor, MI 48109 USA, and also with the Engineering Education Research Program, University of Michigan, Ann Arbor, MI 48109 USA (e-mail: cfinelli@umich.edu).

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classroom. However, these data cannot identify *how* the facilitation of active learning differed in the two classrooms. This question, posed in RQ2, is addressed through qualitative analyses of 37 class observations and 13 instructor interviews.

II. Study Context

This project focused on an *Introduction to Electronics Circuits* course (hereafter referred to as *Circuits*) at a large, public, research-intensive university in the Midwest. The instructor, who had prior experience teaching *Circuits*, taught this course in two consecutive semesters—first in a traditional lecture-based classroom (Fall 2016) and then in a flexible classroom (Winter 2017).

A. Course Description

Circuits is a high-enrollment, required course for undergraduate electrical engineering students. It is taught every Fall and Winter semester, with an average enrollment over the past ten years of 138 students/semester. Topics covered include basic laws of circuits, operational amplifiers, first- and second-order circuits, sinusoids and phasors, AC power analysis, and the frequency response. There is a required laboratory component of the course that is separately administered.

Because of the high enrollment, this course is divided into multiple sections taught by different instructors. Although weekly assignments sometimes vary by section, the course material and exams are the same for all sections. For the two semesters of this project, the course used a digital version of the popular *Fundamentals of Electric Circuits* textbook [21].

In both the Fall 2016 and Winter 2017 semesters, the instructor covered the same 12 chapters of the textbook (Chapters 1-11 and Chapter 14). A student's overall course grade was based on his/her scores on pre-class reading assignments (5%), weekly homework assignments involving problems taken from the course textbook (10%), weekly quizzes (15%), two midterm examinations (15% each), a cumulative final exam (20%), and the grade in the laboratory component of the course (20%).

In both semesters, the instructor's teaching philosophy was to balance lecture and active learning throughout the entire course. She used lectures to reinforce the materials from the pre-class reading and to introduce a number of sample problems. In some instances she worked through the problems in front of the class, while at other times she had students engage in active learning by asking them to work through the sample problems in small groups to practice applying the concepts with their peers.

B. Description of the Flexible Classroom

In Fall 2016, the instructor taught *Circuits* to a class of 89 students in a 156-seat traditional lecture hall with fixed tables and chairs on tiered rows (Fig. 1, top). In the traditional classroom the instructor can write on a large whiteboard spanning the front of the room or wirelessly project material from her laptop or tablet computer to a large screen that can be lowered in front of this whiteboard.

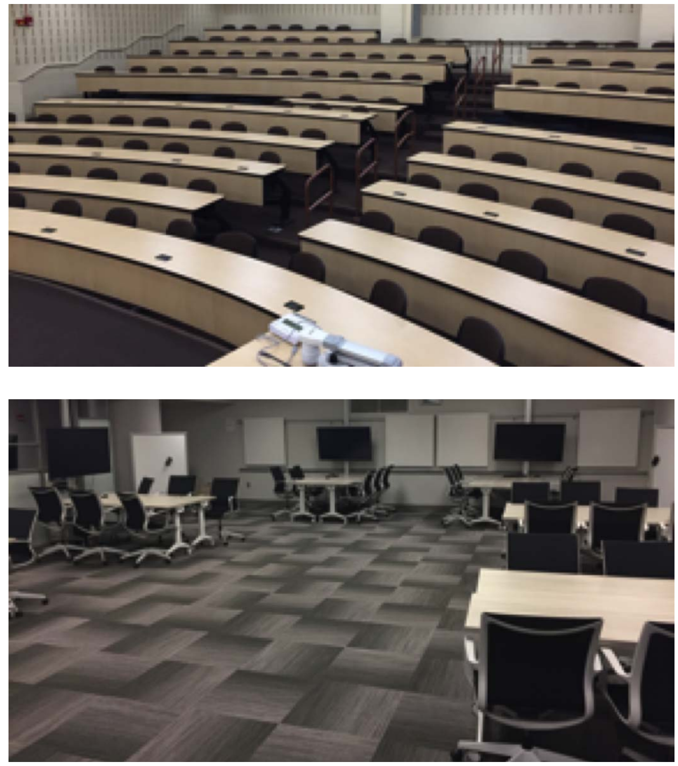

Fig. 1. Pictures of the *Circuits* classroom for Fall 2016 (top) and Winter 2017 (bottom), as taken from the instructor lectern.

In Winter 2017, she taught *Circuits* to a class of 40 students in a recently-renovated 48-seat flexible classroom (Fig. 1, bottom). This flexible classroom features multiple *affordances* that encourage the instructor to use active learning: movable tables and chairs, movable whiteboards, and ultra-high-definition monitors. The flat floor allows the instructor to easily rearrange the movable tables and chairs (both on wheels) into different layouts, such as front-facing rows or small groups. There are whiteboards along the front and back walls, as well as multiple movable whiteboards that can be used by individual student groups. There are also eight 55-inch ultra-high-definition monitors along the walls and one large projector screen at the front of the room. In this flexible classroom the instructor can move freely around the room, wirelessly projecting material from her laptop or tablet computer to the eight monitors from wherever she is, without having to be at the lectern. The instructor can also enable students to connect their own laptops to a monitor or to log into a College of Engineering computer connected to each monitor. Student groups can then each work independently on a computer-based activity on their own monitor. The traditional classroom lacked all of these affordances except a front whiteboard and the ability to wirelessly connect a computer to a front screen.

The normal room layout for *Circuits* was to have eight groups of tables around the periphery of the room, each having space for six students, Fig. 2. This layout was based on the capacity of the classroom and the recommendations of a faculty committee tasked with exploring classroom design. Students were not assigned seats, but observers found that students tended to sit in the same approximate location and work with the same peers throughout the course.

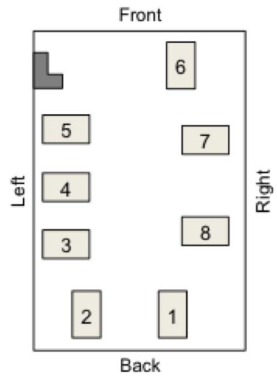

Fig. 2. The flexible classroom layout during Winter 2017.

TABLE I
CHAPTERS TAUGHT IN *Circuits* AND THE PERCENT OF TOPICS APPEARING IN THE VIDEO DATA FOR BOTH SEMESTERS (CHAPTERS SHOWN IN GREY WERE EXCLUDED FROM ANALYSIS DUE TO INSUFFICIENT DATA)

Chapter	Total # Topics in Chapter	# Topics With Video Data	Percent of Data Available
1	5	2	40
2	6	5	83
3	6	1	17
4	6	1	17
5	7	3	43
6	4	3	75
7	5	4	80
8	7	4	57
9	7	7	100
10	6	6	100
11	8	8	100
14	5	4	80

III. METHODS

The two research questions of this study were answered independently using complementary data analysis methods. Research Question 1 (What are the differences in the amount of active learning used by an instructor between flexible classrooms and traditional classrooms?) was addressed through quantitative analysis of 72 coded video lecture recordings from the two semesters. Research Question 2 (How do instructors and students use the affordances of flexible classrooms during active learning?) was addressed through qualitative analysis of 37 class observations and 13 interviews.

A. Video Recordings

To compare the amount of active learning used in the traditional and flexible classrooms (RQ1), 40 lectures were video recorded during the Fall 2016 (traditional classroom) and 32 were recorded during Winter 2017 (flexible classroom) semesters of *Circuits*. The research team viewed the recordings and coded them by applying six *a priori* categories that describe the time spent on different activities. The first category captures *Administrative* time, which includes topics such as the daily agenda, exam information, course logistics, in-class quizzes, and solutions to quiz and exam questions. The remaining five categories capture time spent in different *pedagogical activities*:

1) *Lecture*–the instructor presenting new course concepts,

2) *Instructor-Led Example*–the instructor solidifying a course concept by working through a complete sample problem,

3) *Active Learning (AL) Introduction*–the instructor introducing a problem that the students had to complete in groups,

4) *Active Learning*–students completing the in-class problem with a small group of other students and with optional instructor guidance, and

5) *Active Learning (AL) Recap*–the instructor summarizing the in-class problem with students and answering questions for the whole class.

Two members of the research team each coded the first two class recordings from the Fall 2016 semester to confirm the applicability of the coding scheme, and then one member of the research team independently coded the remainder of the available lecture recordings. The instructor's slides were used as a cue to indicate instances of active learning. Periods of class when the instructor lectured to students and answered students questions (but did not work through sample problems) were coded as *Lecture*. If the instructor completed the entire example on her own, the entire problem was coded as an *Instructor-Led Example*. Although students were taking notes during *Lecture* and *Instructor-Led Examples*, students were only considered to be engaging in active learning when the instructor asked them to work on a problem themselves. The time the instructor spent talking at the beginning of an active learning problem was coded as *AL Introduction*. This ended when the instructor stopped talking to the entire class and gave the students time to work on the problem themselves. This period, coded as *Active Learning*, was when the majority of active student engagement occurred. When the instructor began talking to the entire class once again, describing the problem solution, this time was coded as *AL Recap*. The *AL Recap* periods also included students asking questions and the instructor answering these questions.

For each of the 12 textbook chapters covered during the semester, the percent of time that the instructor devoted to the five pedagogical activities (*Lecture*, *Instructor-Led Example*, *AL Introduction*, *Active Learning*, and *AL Recap*) was calculated from the data. All *Administrative* time was excluded from further analysis, as this was not related to learning new content. Therefore, percents of time spent on each pedagogical activity were calculated by using total class time minus all *Administrative* time. Some class meetings in each semester were not recorded because of there were substitute instructors or technical issues. Thus, for accurate comparison, topics not appearing in the video data for both semesters were removed from the analysis, Table I. Additionally, textbook chapters that had less than 50% of the topics available for analysis were excluded from the analysis.

A two-tailed paired t-test was conducted for each pedagogical activity to ascertain whether there was a significant difference between the semesters in the percent of time spent on that activity. Because five tests were conducted (one for

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each pedagogical activity), a Bonferroni-corrected p-value of $\alpha = 0.01$ was used to indicate significance for each test [22].

B. Class Observations and Interviews

To investigate how instructors and students used the affordances of the flexible classroom during active learning (RQ2), one member of the research team observed all 37 meetings of *Circuits* taught by the instructor under study during the Winter 2017 semester. The observer recorded instructor and student activities in two-minute increments using a standardized observation protocol based on the TDOP (Teaching Dimensions of Practice) protocol [23]. These 37 observations were supplemented with extensive field notes and spatial recordings of the locations where students sat and where the instructor interacted with students.

Researchers also conducted 13 semi-structured interviews with the instructor (one pre-semester interview, one post-semester interview, and 11 interviews during the semester) in which she was asked to reflect on specific events that had occurred in class during the previous week. Unless otherwise indicated, all instructor quotations in this article are taken from these interviews. These 37 observations and 13 interviews focused on how the instructor and students used the different affordances of the room during class, and specifically during active learning.

IV. Differences in the Amount of Active Learning

To answer the first research question (What are the differences in the amount of active learning used by an instructor between flexible classrooms and traditional classrooms?), the quantitative data from the coded video observations were compared for the two semesters. Fig. 3 shows how the pedagogical activities the instructor used changed from Fall 2016 to Winter 2017 when covering the material from each chapter. Data above the *x*-axis indicates that more time was spent on that pedagogical activity during Winter 2017, while data below the *x*-axis indicates that less time was spent on that activity during Winter 2017. Each stacked bar is symmetrical about the *x*-axis, as allocating more time to one activity required taking away an equal percent of time from other activities. Fig. 3 shows that the percent of each chapter spent on active learning-related activities (AL Introduction, Active Learning, and AL Recap) increased from Fall 2016 to Winter 2017, and in response the percent of time spent on *Instructor-Led Examples* decreased.

Table II shows that the decrease in the time spent on *Instructor-Led Examples* from Fall 2016 to Winter 2017 was statistically significant ($p = 0.002$), and the increase in time spent on *Active Learning* was nearly significant ($p = 0.018$). The time spent on *Lecture* stayed almost constant, implying the amount of lecture in class was about the same for both semesters. The time spent on both *AL Introduction* and *AL Recap* was slightly higher for the Winter 2017 semester, as would be expected with the significant increase in time spent on *Active Learning*, but these results were not statistically significant.

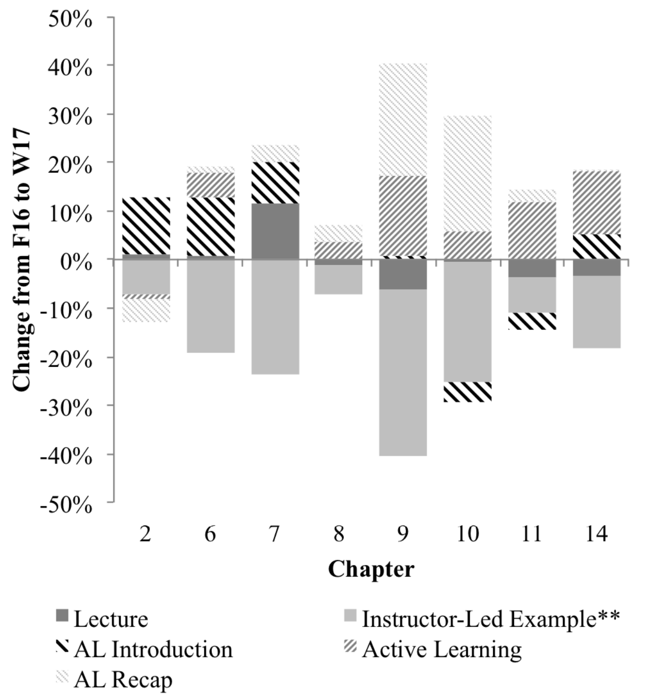

Fig. 3. The change in the percent of each chapter from Fall 2016 to Winter 2017 spent in five pedagogical activities (* indicates $p < 0.01$, ** indicates $p < 0.005$, & *** indicates $p < 0.001$).

V. Flexible Classroom Affordances Used by the Instructor and Students

The quantitative results addressing RQ1 show a significant shift in the pedagogy used in *Circuits* in Winter 2017 from *Instructor-Led Examples* to *Active Learning*. However, these data cannot identify *how* the instructor facilitated active learning differently in the two classrooms. These questions are posed in RQ2 (How do instructors and students use the affordances of flexible classrooms during active learning?) and are addressed through the analysis of qualitative data collected from the 37 class observations and 13 instructor interviews.

In general, the qualitative data show the primary difference between the two implementations of *Circuits* was in the student-instructor and student-peer interactions during periods of *Active Learning*. Details of these interactions are further explored in the following two sections.

A. Interactions Between the Instructor and Students

In an interview at the beginning of the Winter 2017 semester, the instructor described how she rarely initiated interactions with students in the traditional classroom:

> "*And as much as I knew it was good practice to interact with the students at those points, I rarely did that. You know, I felt like I should be asking small groups of students, "What are you doing now?" peering over their shoulders, but I never, I never really did that to much extent.*"

Instead, during *Active Learning* the instructor walked around to answer student-initiated questions and "*make it seem like I was doing something [...] instead of just standing on the stage doing nothing.*"

TABLE II
STATISTICAL ANALYSES OF THE DIFFERENCE IN THE PERCENT OF EACH CHAPTER SPENT IN EACH PEDAGOGICAL ACTIVITY
(* INDICATES $p < 0.01$, ** INDICATES $p < 0.005$, & *** INDICATES $p < 0.001$)

Pedagogical Activity	% of Each Chapter in F16 (μ ± σ)	% of Each Chapter in W17 (μ ± σ)	Difference Between W17 and F16 (μ ± σ)	t-value (7 dof)	p-value
Lecture	24.2 ± 8.7	24.0 ± 8.6	-0.2 ± 5.0	0.10	0.92
Instructor-Led Example	29.9 ± 13.0	12.8 ± 10.4	–17.1 ± 9.4	4.81	0.002**
AL Introduction	10.4 ± 4.3	14.2 ± 4.0	3.8 ± 6.1	1.66	0.14
Active Learning	15.4 ± 7.0	22.2 ± 4.6	6.8 ± 5.9	3.06	0.018
AL Recap	20.2 ± 5.4	26.8 ± 9.6	6.7 ± 9.9	1.79	0.12

When teaching in the flexible classroom in the Winter 2017 semester, the instructor noted that she aimed to increase her interaction with students, and the data show that she achieved this goal. In the 24 video-recorded class meetings that focused on course concepts, there were 89 instances of *Active Learning* with an average duration of 3.53 minutes. The instructor interacted with students in 53 of these instances (60.9%). Furthermore, a statistically significant binomial logistic regression ($\chi^2(1) = 26.16, p < 0.005$) indicates that every additional minute of *Active Learning* doubled the odds of the instructor interacting with students (odds ratio = 2.039).

In the interviews, the instructor noted a number of affordances that enabled her increased interaction with students during active learning. She indicated the smaller class size was beneficial, and she commented that her tablet computer "*allowed me to be untethered from the front of the room but still project what I was doing on the whiteboard.*" She also noted how the small-group classroom layout afforded interaction with more students. In the traditional classroom, one reason that the instructor did not frequently interact with students was that she "*felt like it would be the same students that I would be doing this with again and again because I could only get to the ones right on the edges.*" However, the eight-group layout of the flexible classroom (Fig. 2) allowed the instructor to easily interact with every student during active learning. This was evident in the observational data, as the instructor had between 12 and 20 interactions with each table during the 37 class meetings.

Beyond simply affording more interaction, the instructor also felt the small-group layout afforded *better* interaction with students. In the traditional classroom, she had to lean down to talk with students who remained in their seats. In contrast, the flexible classroom allowed the instructor to sit at a table when there was an empty chair and engage the entire group of students. As she said:

> "*Another thing that I found is sometimes if I just stand at the edge of the table and say, 'Hey, did you get this?' the person closest to me will tell me what he got for an answer. But he might not have been working with the student next to him, which I really wanted them to do, and the student next to them might be lost and might never get a chance to respond. I feel like [sitting down with students is] just a better chance to get in with the students.*"

When the instructor sat with a group, she focused on the process they were using to solve the problem rather than on the final answer. She was observed using phrases such as, "How might we start this problem?" or "Can we work through this together?" when interacting with students to elicit this information. The instructor described her intent in the post-semester interview saying, "*It wasn't so much them telling me what they did, it was us together constructing the solution.*" As the instructor and students worked through the problem, the instructor asked questions and provided feedback. She also wrote out the students' process on her tablet computer, which instantaneously appeared on the front screen and all eight monitors. This gave the other groups material they could refer to as they were solving the problem themselves. The classroom observations show a number of times when students referred to the instructor's projected material to confirm or check their own work.

These improved ways of interacting with students during *Active Learning* also influenced the way in which the instructor facilitated *Active Learning Recap*. When recapping the active learning activity to the entire class, the instructor frequently repeated ideas and questions brought up in her discussion with students. She framed the solution to a problem as a presentation of the students' problem-solving process by using phrases (which the researchers observed) such as, "*I wrote some of the equations your colleagues came up with,*" or, "*I heard another table talking about applying superposition. That also works.*" The instructor was also responsive to unanticipated ideas that came up in her interaction with students. For example, during one interaction a student put forth an alternate process for solving the problem. The instructor recognized this as a valid solution and repeated it to the entire class as a way to "*make sure to sort of validate that student and let the other students in the class know that there are other approaches,*" as she said in an interview. On other occasions, the instructor realized gaps in students' knowledge or misconceptions that she addressed to the entire class. As she said in an interview:

> "*Sitting down with groups of students and walking through the problem [. . .] uncovered things that I could say, 'Oh yeah, wait a minute. Hold that thought, let me explain that to the whole class.' Then I could say, 'By the way, when we are doing this problem don't forget about such and such.*"

B. Interactions Between Students and Their Peers

Qualitative data from the class observations and instructor interviews suggest that students in *Circuits* engaged in active learning by having meaningful discussions with their peers at the same table in groups of two to six. For example, students occasionally continued their discussions about the problem while the instructor began her recap to the entire class, often ignoring the instructor while they talked. The instructor observed this behavior, and remarked in an interview that she was happy to see the students so engaged in the active learning. Individual students also occasionally used the plural pronoun "we" when asking questions or giving an answer to the entire class, which suggests that they internalized the collaborative mindset the instructor aimed to create. Because each table was arranged around the periphery of the room rather than in rows, there was less of a "back of the room" effect as compared to a traditional classroom. Therefore, student participation did not appear to be dependent upon where they sat in the classroom.

In the interviews, the instructor explained how students welcomed her interactions with them and how these interactions appeared to encourage more meaningful participation. She felt these small group interactions made students more comfortable to suggest an answer to the problem, as there were lower stakes for being incorrect. Similarly, the instructor felt that students were more willing to admit that they didn't understand a concept or problem-solving step when she was sitting beside them.

Just as the instructor leveraged the monitors in the room for *AL Recap*, the students used this affordance when interacting with each other. Having the projected material easily visible at their table gave students a focal point on which to base their discussion. In multiple class sessions, students were observed pointing at the material projected on the monitors as they worked through the problem with each other. Students also referred to the monitors as the instructor wrote the solution, checking whether they were correct and answering questions they had asked each other.

VI. Discussion

This paper addresses how the affordances of flexible classrooms influence the amount of active learning used by instructors, interactions between students and their instructor, and interactions between students and their peers. It analyzes qualitative and quantitative data from an *Introduction of Electronic Circuits* course taught in a traditional lecture-based classroom and a flexible classroom over two consecutive semesters. The typical eight-group layout of the flexible classroom afforded more active learning (instead of instructor-led examples) and better student-instructor and student-peer interaction during that active learning.

Close interaction with students gives instructors an opportunity to use *responsive teaching*, a process by which instructors elicit and notice student behavior that gives insight into how and what students are thinking, and then respond by changing the pedagogy or content to emphasize a difficult concept, clarify misconceptions, provide different examples, or go beyond the planned material [24]–[26]. Researchers have demonstrated benefits of responsive teaching, which include enhanced conceptual understanding in students [27], [28] and rich opportunities for student to engage in disciplinary practices [29]–[31]. Throughout the present study, the *Circuits* instructor engaged in responsive teaching during her interaction with student groups and her active learning recap. Thus, these results suggest that instructors who teach in flexible classrooms should be aware of responsive teaching practices and work to enact them when interacting with students during active learning.

The data from this study also demonstrate that students interacted with each other and had meaningful discussions about the problems when the instructor used active learning. This student-peer interaction was facilitated by both the instructor's ability to sit down with students and by the presence of the monitors, an affordance of the classroom that provided a focal point for students' discussions. It is also likely that other affordances of the classroom—particularly the arrangement of tables into small groups, rather than lecture-style rows—encouraged students to interact with their peers. While this hypothesis is not testable with the data collected, previous work on *epistemological framing* suggests that students' judgment about the purpose of active learning and their role in these activities is influenced in part by the physical classroom space [32], [33]. Based on their prior experiences, students may interpret (frame) a room with chairs and front-facing tables as an indication that the class will mostly be lecture and their role will be to listen passively. On the other hand, a flexible classroom with tables arranged in small groups may suggest to students that their role will be to actively discuss and co-construct knowledge with their classmates. Therefore, when asked to do active learning activities, the students in the flexible classroom may be more open to engaging in active learning instruction than the students in the lecture-style classroom. Other research confirms this hypothesis, finding that student resistance to active learning occurs, in part, when the pedagogy violates student expectations of what will occur in the course [34]–[40]. Future research should further address students' epistemological framing in flexible classrooms.

One limitation of this study is that controlled comparisons could not be made between the two implementations of *Circuits* in different classrooms. While the instructor interviews provided an opportunity for the instructor to reflect on her past experience during the Fall 2016 semester of *Circuits*, classroom observational data were not collected during this semester. Furthermore, there were differences between the two semesters of the course, beyond just the physical classroom, such as the size of the class (40 enrolled students in Winter 2017 versus 89 in Fall 2016). This smaller enrollment in Winter 2017 likely contributed to the more and better instructor-student and student-peer interactions observed during this semester. The instructor also made a conscious effort to deepen her interactions with students in Winter 2017, as she knew this was a beneficial instructional practice. The instructor's focus on the students' problem-solving process in Winter 2017 was also the result, in part, of feedback she received from students in the Fall 2016 semester.

While this study did not make controlled comparisons between the two classrooms, the instructor interviews and quantitative data do allow for meaningful comparisons. Furthermore, other research supports these results, finding that teaching in a classroom arranged into small groups of students (as in Fig. 2) encourages instructors to adopt more student-centered pedagogy, such as active learning [41]–[43], and leads to an increase in student-instructor interaction [44], [45].

VII. Conclusion

Some elements of active learning are possible in any classroom [2], [14], but it is made more difficult by classrooms with features such as closely-spaced, tiered rows of fixed seats that do not allow students to interact well with the instructor or their peers [45]. Classroom design literature has advocated for flexible classrooms (e.g., [20]), and the research presented here provides quantitative evidence that the affordances of a flexible classrooms support more active learning. It also goes further by showing through qualitative evidence that even holding the type of active learning constant—such as mathematical problems to be completed in small groups, as discussed in this paper—the affordances of a flexible classroom influence the way the instructor facilitates active learning by enabling more and better instructor-student and student-peer interaction during active learning. While this study focuses on one particular course with a small enrollment, anecdotal evidence demonstrates that instructors of other courses at this university in different engineering disciplines and of different sizes have used the affordances of flexible classrooms for active learning in a way that is similar to that used in *Circuits*. These instructors have made small changes to the way they facilitate active learning in their particular course—employing graduate or undergraduate student teaching assistants to interact with students in a large-enrollment course, for example.

The results of this research support the renovation or construction of flexible classrooms, which is an effective way for universities to encourage instructors to adopt active learning. This research finds specifically that active learning is supported by classroom affordances such as movable furniture that can be rearranged into small groups, multiple wall-mounted monitors, and the ability to wirelessly connect instructors' computers to these monitors and a front screen. When available, instructors who wish to implement active learning more effectively should consider teaching in flexible classrooms, and they should focus on ways to take advantage of the room's affordances to improve their interactions with students and the interactions between students and their peers. Furthermore, administrators and faculty developers should work with these instructors to give them priority in flexible classrooms and provide them with the necessary training and support.

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Aaron W. Johnson received the B.S.E. degree in aerospace engineering from Michigan, USA, and the S.M. and Ph.D. degrees in aeronautics and astronautics from the Massachusetts Institute of Technology. He is a Post-Doctoral Research Fellow in the Engineering Education Research Program and a Lecturer in the Aerospace Engineering Department with the University of Michigan. He transitioned into engineering education research through Post-Doctoral appointments with Tufts University Center for Engineering Education and Outreach and the University of Michigan. His research interests focus on the ways in which students make connections between concepts taught in different courses throughout the curriculum and how they apply this foundational conceptual knowledge in hands-on design courses, labs, and co-curricular experiences.

Max W. Blackburn is currently pursuing the B.S.E. degree in electrical engineering with the Electrical Engineering and Computer Science Department, University of Michigan. His interests lie in studying flexible classroom space affordances and responsive teaching practices, specifically the effects of formative assessment methods in large enrollment courses and how student self-efficacy can be improved through positive interactions with instructors in the classroom.

Magel P. Su received the B.S.E. degree in materials science and engineering from the University of Michigan. He is currently pursuing the Doctoral degree with the Department of Applied Physics and Materials Science, California Institute of Technology. He was a member of the Ultrafast Laser, Material Interaction Laboratory and the Engineering Honors Program with the University of Michigan. He also served as an instructional aide for several courses including Introduction to Engineering, Introduction to Materials and Manufacturing, and Structural and Chemical Characterization of Materials.

Cynthia J. Finelli is an Associate Professor of electrical engineering and computer science, an Associate Professor of education, and the Director of the Engineering Education Research Program with the University of Michigan. Her current research interests include student resistance to active learning, faculty adoption of evidence-based teaching practices, the use of technology and innovative pedagogies on student learning and success, and the impact of a flexible classroom space on faculty teaching and student learning. She is a Deputy Editor of the *Journal for Engineering Education*, an Associate Editor of the IEEE TRANSACTIONS ON EDUCATION, the Past Chair of the Educational Research and Methods Division of ASEE, and a fellow in the American Society of Engineering Education.