Impact of Active Learning Classrooms on Feedback-Supported Student Learning

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Introduction

As student-centered active learning has gained popularity among educators, and evidence of its effectiveness has grown (e.g., [1], [2], [3]), multiple institutions have promoted the creation of active learning classrooms (ALCs) designed to facilitate this pedagogy. Traditional, teacher-centered passive approaches to learning are primarily focused on efficiently presenting subject matter to students through lectures [3]. In contrast, the active learning pedagogy, through in-class activities, hands-on tasks, and more frequent and richer instructional feedback, seeks to engage students in higher order thinking about, and application of, the subject matter.

Crucial to the success of the active learning pedagogy is the instructional feedback and help students receive as they think about and try to apply the subject matter they are studying. As traditional learning classrooms (TLCs), with their typically dense, front-facing seating, tend to limit opportunities for student-student, student-professor, and student-technology interaction, a key focus in active learning classroom design is on creating learning spaces that facilitate rich interactions among students, between students and professors, and between students and instructional content.

Recent ALC designs include: the Student-Centered Active Learning Environment with Upside-down Pedagogies's (SCALE-UP's) classrooms at North Carolina State University, the Active Learning Classrooms (ALCs) at the University of Minnesota, and the Transform, Interact, Learn, Engage (TILE) classrooms at the University of Iowa. Common features of these classrooms are round tables with movable chairs, support for instructional technology, readily accessible whiteboards and microphones, and multiple shared projection screens. Typically, these classrooms also allocate more space per student than traditional classrooms.

Abundant research has reported the positive impact active learning in ALCs can have on students' learning experiences (e.g., [1], [2], [4], [5], [6], [7], [8]). However, as the majority of these studies compared traditional lecture-based instruction in TLCs to active learning in ALCs, the ALC's contribution to this improvement is less well understood. In particular, little is known about the impact that switching from a TLC to an ALC has on students' learning experiences and outcomes when the same active learning pedagogy is used in both classrooms.

We previously reported on the significant positive effects on student learning outcomes and engagement observed in a TLC when the classroom pedagogy was switched from lecture-based instruction to an active learning approach where students mainly engaged in collaborative, professor assisted, problem solving through a web-based problem delivery and feedback system that provided immediate correct-incorrect evaluations of student work [7]. While these positive effects were both encouraging and consistent with other studies (e.g., [2, 4, 5]), the active-learning students' satisfaction with the course did not improve, and the active learning students reported studying for more hours outside of the classroom than students in the original lecture-based course.

The objective of this study was to examine how students' learning outcomes, experiences, and perceptions of the helpfulness of class sessions, changed when the same professor adopted the same web-based problem delivery and feedback supported active learning pedagogy in an ALC instead of a TLC. The following research questions guided the study.

1. Is an ALC a significant factor for students' learning outcomes after controlling for their prior learning outcomes?
2. How do students' learning experiences in an ALC differ from those in a TLC?

Course Structure

The course studied was an introductory electrical circuits course taken by all students, regardless of major, in a four-year engineering program. The course's objectives were to introduce fundamental electrical quantities, components, and concepts, and to develop students' ad hoc and systematic circuit analysis skills. The course consisted of three weekly 50-minute class sessions taught by a professor and one weekly 50-minute discussion session led by a teaching assistant. As part of a previous study, [7], the professor had transformed the course from lecture-based instruction in a TLC, to active learning instruction in the same classroom by replacing 40 minutes of lecture with 40 minutes of collaborative, professor assisted, student problem solving activities supported by a web-based problem delivery and feedback system. A TLC class session from the transformed course is pictured in Figure 1.

Figure 1. Active learning circuits class session in a TLC (author photo).

For the current study the same professor taught the same active learning electrical circuits course in the ALC pictured in Figure 2 using the same syllabus, classroom activities, assessments, and web-based problem delivery and feedback system. In both classrooms, each class session began with a 10-minute lecture. Students spent the remaining 40 minutes of class time solving 4-6 problems that opened on a web-based problem delivery and feedback system 10 minutes into class and closed at the end of class. Students accessed the problems using a personal, Wi-Fi enabled, smart device (e.g., a laptop, tablet, or smart phone) that they brought to class; worked each problem on paper in a notebook; and then entered their answers into the web-based problem delivery and feedback system for immediate evaluation.

Figure 2. Active learning circuits class session in an ALC (university photo).

Throughout both classes' problem-solving sessions students were encouraged to collaborate and seek help from classmates, circulating teaching assistants, or the professor. To encourage attendance and problem ownership, all submitted answers were scored in real-time by the web-based problem delivery and feedback system and counted towards students' final grades. To encourage students to more rapidly identify when they needed help, up to three answer submissions per problem were permitted without penalty. Finally, to encourage students to share approaches to solving problems as opposed to specific answers, the web-based problem delivery and feedback system was programmed to provide a different parameterization of each problem to each student.

An annotated illustration of a typical student interaction with the web-based problem delivery and feedback system is shown in Figure 3. In addition to supporting the randomization of the parameters of auto-graded numerical problems, the system, Mastering Engineering™, supports the auto-grading of symbolic problems. For instance, it can recognize all correct answers to the symbolic question posed in Figure 3(a), Part A. As illustrated in Figure 3(d), it is also capable of providing appropriate hints in response to incorrect answers (e.g., check your signs, check your scaling, check your units, the correct answer does not depend on R_3). All 500+ Mastering Engineering problems assigned in the TLC and ALC courses were coded by the course professor and two research assistants in XML (eXtensible Markup Language) using a proprietary Mastering Engineering editor [9].

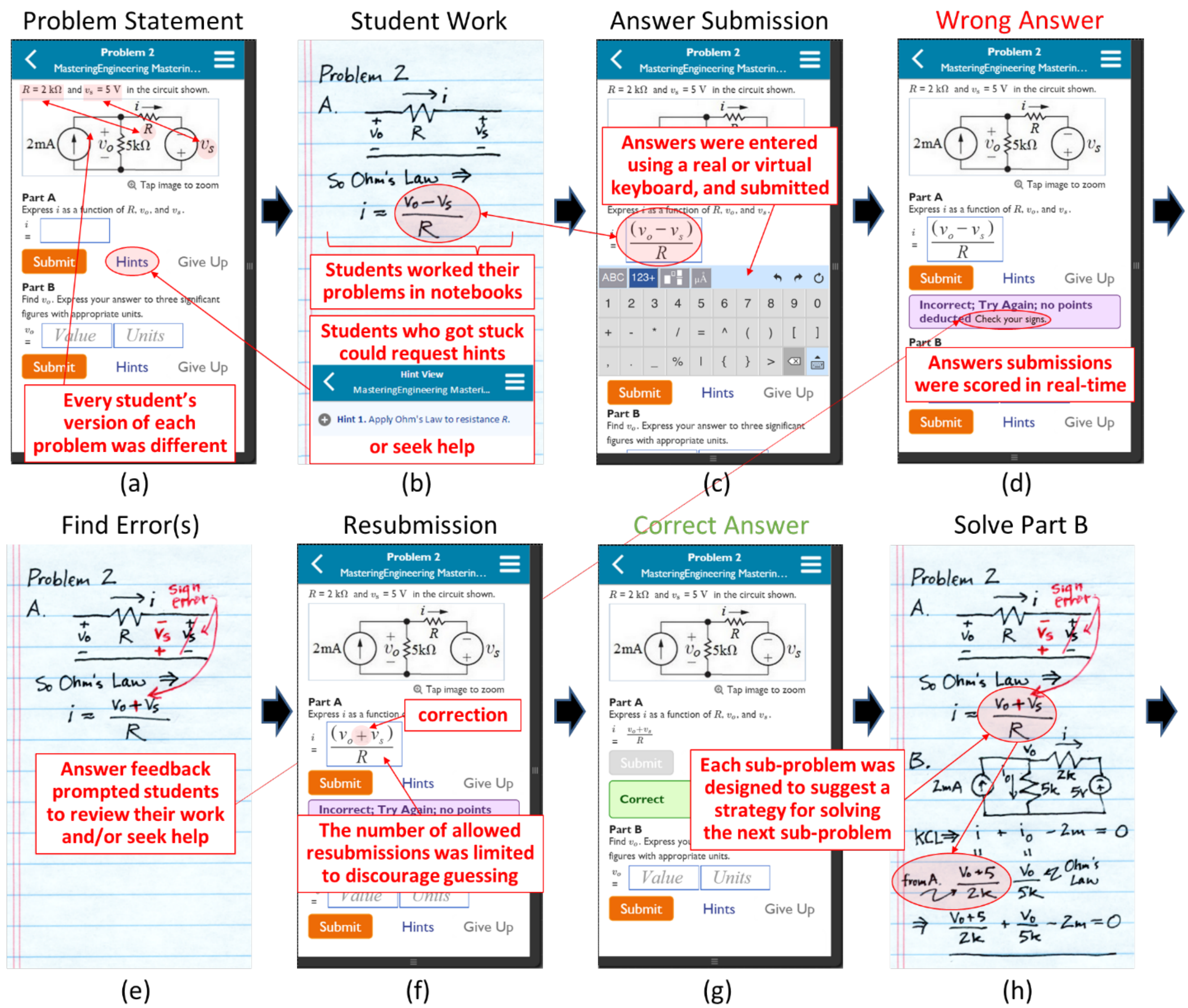

Figure 3. Annotated illustration of a student's interaction with the Mastering Engineering^{TM} web-based problem delivery and feedback system on an iPhone 5s in both the traditional learning classroom (TLC) and active learning classroom (ALC) versions of the active learning circuits course. Reprinted from [7].

Because lecture time was limited to ten minutes per class, supplemental materials, including short lecture videos on each topic, lecture notes, and related problem-solving videos were posted on the course website prior to each class. Additionally, prior to each class a few relatively easy practice problems were made available on the web-based problem delivery and feedback system so that students could work problems similar to the ones they would encounter during their class session before coming to class.

The total number of students in the TLC was much larger than the number in the ALC (142 vs. 65). Accordingly, to maintain a roughly equivalent student to teaching assistant ratio, more teaching assistants were assigned to the TLC course than to the ALC course (1 to 20 vs. 1 to 22). In both the TLC and ALC courses the teaching assistants' responsibilities were the same—to lead a weekly problem-solving discussion session, to assist students during the problem-solving portion of class sessions, and to provide office hours. Table 1 summarizes the course structure of both the TLC and ALC offerings of the active learning circuits course.

Table 1: TLC and ALC Active Learning Circuits Course Structure.

Pre-class	Text Readings Lecture videos (6-18 minutes) optional supplemental materials 3-6 optional pre-class problems (web distributed and scored)
In-class	Lecture (10 minutes) 4-6 graded in-class problems (web distributed and scored)
Post-class	A weekly discussion led by a TA 6-7 graded weekly homework problems (web distributed and scored)
Assessment	2 midterms and 1 final (80%) Homework (12 assignments, lowest 2 dropped) 10% In-class problems (43 assignments, lowest 6 dropped) 10%
Teaching assistants' role	Lead a weekly discussion Help students during class Provide office hours
Essential Technology	Mastering Engineering™ Robust classroom Wi-Fi Wi-Fi capable student smart devices

Methods

A university teaching, learning and technology research team collaborated with the course professor to conduct the study. All students in both the TLC and ALC courses were invited to complete three surveys during the semester—one at the beginning of the semester, one in the middle of the semester, and one at the end of the semester. The first survey assessed students' self-efficacy, intrinsic values, and test anxiety [10]. The second survey included questions concerning students' perceptions of the helpfulness of the class sessions and study hours in a typical week. The third survey reassessed students' self-efficacy, intrinsic values and test anxiety, helpfulness of the class sessions, and study hours. Additionally, questions concerning students' level of engagement, [11], [12], and satisfaction with the course were asked. The measures of self-efficacy (9 items), intrinsic value (9 items), and test anxiety (4 items) were adopted from [10]. The alpha reliabilities in the current study were: self-efficacy, .94, intrinsic value, .90, and test anxiety .92. After the course was completed students' demographic information, prior learning outcomes (cumulative GPA), and exam scores, were collected. All research protocols were approved by the university's institutional review board and all student participants received compensation ($5 per survey) for the time they spent completing surveys.

Participants

One hundred and seventy-nine students participated in the study, 116 (82%) from the TLC course, and 63 (95%) from the ALC course. Among the participating students, 26% were female, 28% were non-white, and 71% were sophomores. There were no significant differences between the two classrooms' demographic factors. There was, however, a significant difference between the two courses' students' prior learning outcomes. In particular, the mean prior cumulative graduate point average (GPA) of students in the TLC course was 3.35/4.00 while the mean prior cumulative GPA of students in the ALC course was only 2.97/4.00.

Results

Course Learning Outcomes

Eighty percent of each course's grade was determined by three exams (two midterms and one final). The exams administered in each course were identical. Each exam consisted of 18 problems and had a maximum score of 90 points. The mean exam scores and final course grades of students in both courses were similar even though the ALC course's students had significantly lower prior learning outcomes (Table 2).

Table 2. Descriptive statistics for students' exam scores, final grades, and prior GPAs.

	TLC students			ALC students		
	N	mean	SD	N	mean	SD
Midterm1	111	59.19	18.99	63	60.56	19.86
Midterm2	110	57.36	18.89	63	57.86	20.65
Final exam	111	50.96	18.32	63	49.52	20.51
Course grades	111	2.83	1.00	63	2.78	1.00
Prior cumulative GPA	111	3.35	0.46	63	2.97	0.58

Multiple regression analyses indicate that the ALC was a significant predictor of students' mean exam scores and course grades when prior cumulative GPA was added as a covariate with a classroom variable (Table 3). Specifically, the analyses show that after controlling for students' prior GPA, the predicted mean midterm 1, midterm 2, and final exam scores for ALC students would be, respectively, 9.09 (midterm 1), 8.65 (midterm 2), and 6.02 (final exam) points higher than for TLC students. Further, after controlling for prior GPA, the predicted mean course grade for the ALC students would be almost half a grade point (0.44) higher than for the TLC students.

Table 3. Multiple regression exam score and final grade prediction results.

	Midterm 1				
	Estimate	Standard error	DF	t Value	p
Prior cumulative GPA	20.91	2.47	169	8.48	< .0001
Active learning classroom	9.09	2.75	169	3.31	.0012
	Midterm 2				
Prior cumulative GPA	22.81	2.39	169	9.53	< .0001
Active learning classroom	8.65	2.67	169	3.24	.0015
	Final exam				
Prior cumulative GPA	21.01	2.41	169	8.72	< .0001
Active learning classroom	6.02	2.67	169	2.24	.02
	Course grade				
Prior cumulative GPA	1.36	0.11	169	12.31	< .0001
Active learning classroom	0.44	0.12	169	3.59	.0004

Motivational Factors and Engagement

Three component motivational factors (self-efficacy, intrinsic value, and test anxiety), and three aspects of engagement (behavior, emotional, and cognitive) were also assessed. The motivational factors were assessed at both the beginning and end of the semester to capture any classroom effects on student motivation at the end of the semester. Results indicated that there were no significant differences in motivational factors and engagement between the classrooms' students (Table 4). Students' perceptions of their preparedness prior to class, and their perceptions of their problem-solving and critical thinking skill improvement, were also similar in both classrooms.

Table 4. Results of independent t tests and descriptive statistics for student reported attendance, helpfulness of class sessions, engagement, motivation, preparedness, learning from mistakes, improvement of problem solving skills, improvement of critical thinking skills, and satisfaction.

	TLC			ALC		
	N	mean (SD)		N	mean (SD)	t
Attending class						
Middle of the semester	100	2.92/3 (0.44)		45	2.82/3 (0.58)	1.12
End of the semester	63	2.78/3 (0.71)		30	2.77/3 (0.57)	0.08
Helpfulness of class sessions						
Middle of the semester	93	3.99 (1.82)		45	4.89 (1.70)	-2.78**
End of the semester	100	3.65 (1.86)		48	5.13 (1.45)	-4.48**
Engagement (post)	92	4.51 (1.11)		44	4.54 (1.02)	-0.17
Behavioral	91	5.16 (0.99)		44	5.16 (0.99)	1.07
Emotional	91	3.78 (1.41)		44	4.18 (1.48)	-1.51
Cognitive	91	4.34 (1.57)		44	4.22 (1.28)	0.45

Motivation						
Self-efficacy (pre)	116	5.52 (0.83)		63	5.62 (0.86)	-0.77
Self-efficacy (post)	92	4.79 (1.28)		44	5.01 (1.25)	-0.92
Intrinsic value (pre)	116	5.35 (0.96)		63	5.41 (1.05)	-0.37
Intrinsic value (post)	92	4.43 (1.32)		44	4.53 (1.34)	0.40
Test anxiety (pre)	116	3.87 (1.51)		63	3.67 (1.66)	0.78
Test anxiety (post)	92	4.21 (1.66)		44	3.78 (1.66)	1.41
Preparedness	91	4.47 (1.51)		44	4.39 (1.85)	0.29
Learn from mistakes	92	4.55 (1.97)		44	5.27 (1.66)	-2.1*
Improved						
Problem solving skill	92	4.37 (1.57)		44	4.80 (1.46)	-1.51
Critical thinking skill	92	4.43 (1.61)		44	4.89 (1.35)	-1.61
Satisfaction	91	3.34 (1.93)		44	4.27 (1.82)	-2.67**

Note: All variables in the self-reported survey were measured using a 7-point Likert type scale. "pre" indicates that the survey was administered at the beginning of the semester. "post" indicates that the survey was administered at the end of the semester. Satisfaction = Overall satisfaction with the course. *p < .05, **p < .01, ***p < .001.

On the other hand, several significant differences were observed. While both classrooms' students reported attending class consistently throughout the semester, with averages ranging from 2.77 to 2.92 times per week, the ALC's students' perception of the helpfulness of attending class was always significantly higher and grew with time (Table 4). The ALC's students' perception that they learned from their problem-solving mistakes was also higher. Taken together, these results may explain why the ALC's students' overall satisfaction with their course was significantly higher than that of the TLC's students (Table 4).

Most interestingly, there were also significant differences between the two classrooms' students with respect to self-reported study hours by the end of the two classes' semesters. There was no significant difference in expected study hours when we asked at the beginning of the semester. However, the ALC students reported studying significantly fewer hours than the TLC students at the middle and end of the semester (Figure 4).

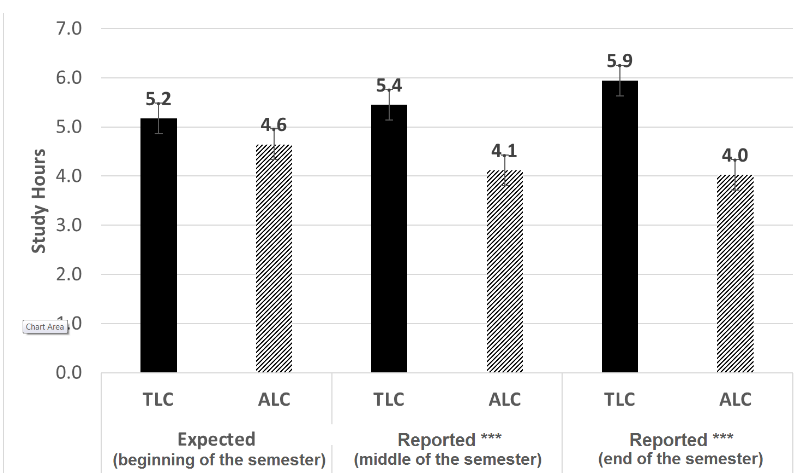

Figure 4. Self-reported TLC and ALC student study hours in a typical week. ***p < .001

Student Comments

One section of the students' surveys asked them to elaborate on what they found to be the most challenging and helpful aspects of the course with respect to their learning. Among the TLC student responses, two major themes emerged for the most challenging aspect: 'classroom setting' and 'learning on my own'. Many students from the TLC viewed the course as a self-taught course, and perceived the classroom setting as being inadequate for teamwork. Typical TLC most challenging aspects student responses, extracted directly from the survey, included:

> *"Not being taught by a teacher"*
>
> *"Teaching myself how to solve problems"*
>
> *"The setting. The lecture hall and massive class size made teamwork very difficult"*

On the other hand, among the ALC student responses, the major theme that emerged for the most challenging aspect was 'completing in-class problems', and no student viewed the course as self-taught. Typical most challenging aspect ALC student responses extracted directly from the survey included:

> *"There is NOT enough time if you have a question to get that answered and complete all the questions."*
>
> *"In class assignments, not enough time to do all the work."*
>
> *"I usually felt rushed when completing the in-class assignments."*

The common theme for the most helpful aspect of the course among both classrooms' students was 'in-class problems'. An additional theme in the ALC's student responses was: 'working with peers.' Typical most helpful aspect ALC student responses extracted directly from the survey included:

> *"Peers at my table"*
>
> *"I did enjoy working with other students in class to solve problems together. That was a good way to learn the material."*
>
> *"Getting help from my peers when I wasn't sure about a problem"*
>
> *"Working problems with others during class time."*

Discussion

The main objective of this study was to investigate the impact ALCs have on students' active learning outcomes and experiences. To accomplish this, we examined how students' learning outcomes, experiences, and perceptions of the helpfulness of class sessions, changed when the same professor adopted the same web-based problem delivery and feedback system supported active learning pedagogy in an ALC instead of a TLC. Our results indicate that students in the ALC achieved higher scores on all exams and achieved better course grades than the students in the TLC after controlling for their prior learning outcomes. In addition, the results indicate that the students in the ALC perceived the class sessions to be more helpful and expressed higher satisfaction with their course than the students in the TLC.

These results not only support previous findings that active learning instruction in ALCs contributes positively to students' learning experiences and outcomes (e.g., [1], [4], [5], [6], [13]), but suggest that with respect to outcomes, students' perceptions of the usefulness of class sessions, and students' perceptions of how hard they have to work to be successful, the ALC enhances the effectiveness of the active learning pedagogy.

Although the course professor in this study provided the same learning materials and facilitated the same active learning activities with identical technology in both classrooms, students' perceptions of the effectiveness of instruction in the two classrooms were different. Students in the ALC perceived their class sessions to be significantly more helpful and were more satisfied with their course than students in the TLC. More importantly and surprisingly, students in the ALC achieved the same learning outcomes as students in the TLC despite having prior learning outcomes that were significantly lower than the TLC students, and despite reporting that they spent significantly fewer hours studying outside of the classroom than the TLC students.

In both classrooms, the web-based problem delivery and feedback system supported active learning pedagogy adopted by the professor offered students multiple opportunities for frequent and rich instructional interactions. All students received correct-incorrect feedback and problem-solving hints from the web-based system after every answer submission, and although each student had to solve a unique version of most problems, most discussed solution strategies with classmates, and at one time or another, received help from a teaching assistant or the professor.

In the TLC, however, most students could only easily interact with neighboring classmates, and those seated in the middle of blocks of seats could not easily be reached by the teaching assistants or professor when they needed help. Additionally, the fixed, closely spaced seats left little room for students to comfortably manage their smart devices, paper notebook, and other belongings. In contrast, in the ALC, the up to nine students seated at each table could easily interact and could easily be reached by the teaching assistants and professor wherever they sat. Moreover, there was ample space for their belongings, and if they wished to share an idea, they could do so on an adjacent whiteboard rather than having to exchange electronic or paper notes.

In short, one reason that the ALC students outperformed the TLC students relative to their prior learning outcomes while reporting spending fewer hours studying than the TLC students could be that the accessibility and extra space afforded by the ALC simply made it easier for the ALC students to use their active learning time efficiently. While the majority of students in both classrooms reported that the web-based in-class problem solving was the most helpful aspect of their course with respect to their learning, only the TLC students cited their classroom as a barrier to cooperative learning. In fact, while many students from the TLC course viewed their course as being self-taught, no students from the ALC course expressed that feeling. Instead, the ALC students seemed to enjoy working problems with classmates.

Despite the fact that TLC and ALC students received the same active learning instruction using the same technology, their learning experiences in the two classrooms were different. These findings suggest that learning spaces, especially the accessibility and space they provide, can have a significant impact on student learning experiences and outcomes.

Future Directions

This study provides strong evidence that the learning experiences and outcomes that can be achieved by the active learning pedagogy in TLCs can be enhanced by moving the pedagogy to ALCs. However, because in this study the TLC course size was more than double that of the ALC course size, further research will be needed to determine whether the results will continue to hold as ALC course size increases.

References

[1] S. Cotner, J. Loper, J.D. Walker, and D.C. Brooks, "It's not you, it's the room—Are the high-tech, active learning classrooms worth it?" *Journal of College Science Teaching*, vol. 42 no. 6, pp. 82-88, July 2013.

[2] S. Freeman, S. Eddy, M. McDonough, M. Smith, N. Okoroafor, H. Jordt, and M. Wenderoth, "Active learning increases student performance in science, engineering, and mathematics," *Proc Natl Acad Sci*, vol. 111, no. 23, pp. 8410-8415, June 2014.

[3] R.S. Grabinger and J.C. Dunlap, "Rich environments for active learning: A definition," *Research in Learning Technology*, vol. 3, no. 2, pp. 5-34, 1995.

[4] P. Baepler, J.D. Walker, and M. Driessen, "It's not about seat time: Blending, flipping, and efficiency in active learning classrooms," *Computers & Education*, vol. 78, pp. 227-236, Sept. 2014.

[5] D.C. Brooks, "Space matters: The impact of formal learning environments on student learning," *British Journal of Educational Technology*, vol. 42, no. 5, pp. 719-726, Sept. 2011.

[6] P. Chiu, and S.H. Cheng, "Effects of active learning classrooms on student learning: a two-year empirical investigation on student perceptions and academic performance," *Higher Education Research & Development*, vol. 36, no. 2, pp. 269-279, 2017.

[7] J. Russell, M. Andersland, S. Van Horne, J. Gikonyo, and L. Sloan, "Large lecture transformation: Improving student engagement and performance through in-class practice in an electrical circuits course," *Advances in Engineering Education*, vol. 6, no. 2, Oct. 2017. [Online]. Available: https://advances.asee.org/2017/10/. [Accessed Apr. 27, 2019].

[8] F. Durham, J. Russell, S. Van Horne, “Assessing student engagement: A collaborative curriculum for large lecture discussion sections,” *Journalism and Mass Communication Educator*, vol. 73, no. 2, pp. 218-236, June 2018.

[9] Pearson Education Inc, *Mastering Advanced Editor Help*. [Online]. Available: https://help.pearsoncmg.com/mastering/authoring/adv_editor/. [Accessed Apr. 27, 2019].

[10] P.R. Pintrich, and E.V. De Groot, “Motivational and self-regulated learning components of classroom academic performance,” *Journal of Educational Psychology*, vol. 82, no. 1, pp. 33-40, Mar. 1990.

[11] C. Senko and K.M. Miles, “Pursuing their own learning agenda: How mastery-oriented students jeopardize their class performance,” *Contemporary Educational Psychology*, vol. 33, no. 4, pp. 561-583, Oct. 2008.

[12] E.A. Skinner, T.A. Kindermann, and C.J. Furrer, “A motivational perspective on engagement and disaffection: Conceptualization and assessment of children’s behavioral and emotional participation in academic activities in the classroom,” *Educational and Psychological Measurement*, vol. 69, no. 3, pp. 493-525, June 2009.

[13] B. Wiggins, S. Eddy, L. Wener-Fligner, K. Freisem, D. Grunspan, E. Theobald, J. Timbrook, and A. Crowe, “ASPECT: A survey to assess student perspective of engagement an active-learning classroom,” *CBE Life Sci Educ*, vol. 16, no. 2, June 2017. [Online]. Available: https://www.lifescied.org/toc/lse/16/2. [Accessed Apr. 27, 2019].