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It's not about seat time: Blending, flipping, and efficiency in active learning classrooms

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ABSTRACT

This study examines the effect of reducing the seat time of a large lecture chemistry class by two-thirds and conducting it in an active learning classroom rather than a traditional amphitheater. To account for the reduced lecture, didactic content was recorded and posted online for viewing outside of the classroom. A second experimental section, also in a blended and flipped format, was examined the following semester as a replication. To measure student subject-matter learning, we used a standardized multiple-choice exam, and to measure student perceptions of the classroom, we used a validated survey instrument. Our findings demonstrated that in an active learning classroom, student faculty contact could be reduced by two-thirds and students achieved learning outcomes that were at least as good, and in one comparison significantly better than, those in a traditional classroom. Concurrently, student perceptions of the learning environment were improved. This suggests that pedagogically speaking, active learning classrooms, though they seat fewer students per square foot, are actually a more efficient use of physical space.

1. Introduction

As economic pressures demand that universities graduate more students, physical classroom space has grown increasingly scarce. Many colleges are experiencing rising enrollments and, consequently, large class sizes are common. Some pressure on classroom space has been relieved as the technology and infrastructure to put lectures online has matured and been made easier. More courses are being offered entirely online, and some courses have been flipped, placing didactic lectures on the web and using face-to-face time to build conceptual understanding and cognitive skills. Typically this is done using some form of active learning or any number of what Edgerton (2001) termed "pedagogies of engagement," a concept, that as Smith, Sheppard, Johnson, and Johnson (2005) noted, was prefigured in the foundational publication, *The Seven Principles for Good Practice in Undergraduate* Education (Chickering & Gamson, 1987). These pedagogies have many names: POGIL (process-oriented, guided-inquire learning), peer learning, team based learning (TBL), cooperative learning, and more.

Although these methods have certainly worked in traditional classrooms (Deslauriers, Schelew, & Wieman, 2011; Lyon & Lagowski, 2008; Mazur, 2009), the environment of a large lecture hall with fixed seating in rows makes peer collaboration difficult and awkward. A better environment for these pedagogies would be a room designed to facilitate small group work, such as an active learning classroom (ALC). Currently, however, extremely large active learning classrooms that can accommodate class sizes of over 350 do not exist, and it is not clear that ALCs of that size would be workable in any case (Baepler et al., 2013). The only way to teach such a large class without increasing the amount of time an instructor spends in the classroom is to blend and flip the course; that is, split the section into three parts that meet only once a week rather than 3 times each week, and move online a large portion of the course's learning activities, which were previously conducted face-to-face.

To do this, however, would mean reducing the number of hours students spend in the classroom by two thirds. Many instructors and administrators believe that reducing instructor-student contact should hinder student learning because the quantity of interaction with

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faculty members—asking and answering questions during lecture, for example—is positively associated with the learning outcomes students achieve. Theoretically, less time in the classroom should result in lower student performance. The current study was designed to test this contention, by determining whether the use of active learning spaces in tandem with a flipped and blended classroom model could overcome the anticipated reduction in student learning outcomes hypothetically to be expected from decreased face-to-face instructional time. The study has a practical implication as well. Those administrators and planners who are considering building and retrofitting new spaces are concerned with the financial cost of these classrooms. A secondary concern of this study is to shed light on the potential efficiencies and cost savings of the blended model in the active learning classroom.

The research question guiding this study was as follows: Can student inclass time and student-faculty face-to-face contact time be reduced by 66% without undermining the student learning experience or student learning outcomes by moving the course from a traditional format to a flipped, blended ALC-based format?

1.1. Active learning classrooms

In the recent past, several alternative classroom designs that support active and collaborative learning have emerged (Gierdowski, 2013; Oblinger, 2006). With names like Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP), Technology Enabled Active Learning (TEAL), and Spaces to Transform, Interact Learning, Engage (TILE), these ALCs typically feature tables with moveable seating that support small group work. The tables are often paired with additional learning technologies such as whiteboards and student computer-projection capabilities for sharing work, microphones to hear student voices, and wireless Internet access to retrieve resources (Fig. 1). The net effect of the classroom design is to create a learning environment in support of active learning pedagogy and collaborative problem solving. These new designs have been adopted in small and large scale. For example, the University of Minnesota has over 20 ALCs, and the University of Southern California is in the process of reengineering 185 classrooms and 20 auditoriums (Demski, 2012).

Empirical research on active learning classrooms can be traced to courses in physics education at North Carolina State University, which, in contrast to similar courses taught in traditional classrooms, recorded gains in students' conceptual understanding and improved attitudes (Beichner et al., 2007). Similar gains were found in physics courses at the Massachusetts Institute of Technology, and researchers noted the importance of social interactions—a key target of the learning environment design—in how students developed their conceptual understanding (Dori & Belcher, 2005). After 6 years of study at the University of Minnesota in multiple disciplines and using quasi-experimental designs to control for a myriad of influences and isolate the effects of different learning spaces, researchers concluded that indeed "space matters." The researchers found that students in active learning classrooms outperformed aptitude-based expectations in terms of learning outcomes when compared to students in traditional classrooms; students also perceived that the space in active learning classrooms is

Fig. 1. An Active Learning Classroom, characterized by round tables, microphones, large-screen monitors, whiteboards, and wireless.

Fig. 2. The traditional classroom in which the control class was held.

superior to that in traditional rooms on a host of attributes including engagement, enrichment, confidence, effective use, room/course fit, and flexibility (Brooks, 2011; Walker, Brooks, & Baepler, 2011; Whiteside, Brooks, & Walker, 2010).

1.2. The flipped classroom and blended learning

The flipped or inverted classroom refers to a learning design that upends the typical division of student work (Vignare, 2007). Lectures are moved online to be viewed before class, and classroom time is dedicated to learning activities that require students to engage concepts at a higher level in a group setting and with an instructor at hand to answer questions, give feedback, and prompt reexamination of key ideas. Several studies in various disciplines have shown that a flipped classroom can produce better learning outcomes as it increases levels of problem solving structure and practice (Berrett, 2012; Deslauriers et al., 2011; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Missildine, Fountain, Summers, & Gosselin, 2013). Students are compelled to make a different type of contribution to their own learning as they work through problems in class and teach each other. Students can find the inverted approach disconcerting at first, however, and some remain dissatisfied with the change in the traditional approach despite the learning gains (Missildine et al., 2013; Strayer, 2012).

The inverted classroom can sometimes play a significant role in blended learning. Although there is no single definition of what constitutes blended learning, many agree that a lack of a tight description gives the concept enough malleability to be useful in many contexts (Graham, 2013). For the purposes of this study, we take the common understanding of the term as a mode of instruction that combines face-to-face classroom time with online instruction. This can take many forms, and some even insist that a particular percentage of the course (e.g. 50% or more) must occur online in order to be considered a blended course (Bernard, Borokhovski, Schmid, Tamim, & Abrami, 2014). Although we don't adhere to such limits, any common definition of the term certainly implies that students spend less time in a physical classroom. Because it requires less time in a physical space, blended learning courses can also lead to cost efficiencies by reassigning remaindered classroom time to other courses (Graham, 2013). One of the most revealing findings of the Department of Education's 2010 landmark review of empirical studies on online learning was that students in blended learning courses achieve, on average, learning outcomes superior to those of their counterparts in fully online or traditional face-to-face classes (Means, Toyama, Murphy, & Bakia 2013; Means, Toyama, Murphy, Bakia, & Jones, 2010). Additionally, when contrasted with traditional lecture courses, student satisfaction tends to be higher in blended learning classes (Kelly, Lyng, McGrath, & Cannon, 2009; Martínez-Caro & Campuzano-Bolarin, 2011). Institutionally, blended learning brings administrative advantages since theoretically it can reduce the need for time in the physical classroom and hence alleviate pressure on classroom scheduling.

Table 1
Initial study: Differences between traditional classroom and ALC on age, cumulative GPA, and composite ACT.

	Traditional classroom (Spring 2012)	Active learning classroom (Fall 2012)	Difference	t statistic
Age	19.61	19.66	.05	.287
	(2.11)	(2.66)		
	340	340		
Cumulative GPA	3.07	2.97	−.10	−1.89
	(.61)	(.73)		
	339	337		
Composite ACT	26.40	27.41	1.01	3.66***
	(3.26)	(3.40)		
	298	283		

Note: Cell entries are means, standard deviations (in parentheses), and N. *$p < .05$, **$p < .01$, ***$p < .001$.

2. Methods

2.1. Design

This study used a posttest-only nonequivalent groups design involving undergraduate students in three sections of a General Chemistry course at an R-1 institution in the Midwest. Students in the control group (spring 2012) attended class 3 times a week (150 min per week) in a theater-style classroom with 350 students (Fig. 2). They listened to lectures, watched demonstrations, and responded to the instructor's questions and prompts. During the following semester (fall 2012) the experimental group was split into three sub-groups; each sub-group attended class just once a week (50 min per week) in an ALC with capacity for 117 students. They had access to optional online lectures, solved problems in small groups during class, worked with computer simulations, played a chemistry version of the game Jeopardy, and answered clicker questions. A second experimental section of the class, also in blended/flipped format, was held in spring 2013 as a replication.

Because students self-selected into the class, random assignment to experimental and control conditions was not possible. The instructor, course content and objectives, and main course assessments were held constant. The time of day and the semester varied due to scheduling needs, and the classroom and flipped pedagogy were allowed to vary to create the conditions in this quasi-experiment.

2.2. Participants

The participants in this study included all students in three sections of CHEM 1061 General Chemistry, excluding students in a graduate program, those who withdrew from the course, and the five students who were under the age of 18 and could not be included due to the IRB requirements. On the first day of each semester, students were given an opportunity to opt out of the study; nobody chose this option. All students were surveyed on the final day of instruction using a paper Scantron survey form that was electronically tabulated by the university's Office of Measurement Services. Their grade data were collected from the instructor, and their demographic data were received from the university's Office of Institutional Research. The total number of students across three semesters (spring 2012, fall 2012, and spring 2013) was 1100.

2.3. Instrument and measures

To measure student subject matter learning, students in this study completed two examinations. First, they completed a 20-item multiple-choice examination (GC08C) developed by the American Chemical Society's (ACS) Division of Chemical Education Examinations Institute. In all three semesters, the exam was administered in a traditional classroom setting—not in the active learning classroom—to minimize the potential for cheating and to regularize the timing of the exam across all sections of CHEM 1061. Students were allotted exactly 50 min to complete the exam. All copies of this examination were collected prior to the administration of a second and separate exam created independently by section instructors and consisting of 40 items.

As part of the course, students took three instructor-generated midterm tests that were proctored in a similar fashion as the final. They also responded to clicker questions in class and homework questions online. None of these measures were included in the analysis because they varied between semesters. Students were also required to register for a one-credit lab, but as is typical with this course, students' lab work was graded separately from the course and treated as an independent component.

To assess the impact of the ALCs on students' learning experience, this study also used a validated 32-item survey instrument. (The survey included 25 additional items that measured the frequency of particular learning activities and also the ease of classroom usability; these topics are not considered here.) The instrument contained items designed to measure student perceptions of the degree to which a classroom promotes engagement, enriches students' learning experiences, allows flexibility in approaches to learning, is a good fit to the course being taken, is used well by the instructor, engenders confidence in academic tasks, and facilitates key student learning outcomes. Each of these constructs was identified via exploratory factor analysis, met the criteria for construct validity, and was highly reliable (Cronbach's $\alpha > .85$ for each of the scales; Whiteside et al., 2010).

2.4. Preliminary data analyses

All data were consolidated into a single Microsoft Excel spreadsheet, filtered for anomalies, and uploaded into PASW (previously SPSS) Statistics 21. Because participants were not randomly assigned to control and treatment conditions in this study, it was important to establish comparability of the groups on the available exogenous variables, which included aptitude variables (composite ACT score, GPA)

Table 2
Replication study: Differences between traditional classroom and ALC on age, cumulative GPA, and composite ACT.

	Traditional classroom (Spring 2012)	Active learning classroom (Spring 2013)	Difference	*t* statistic
Age	19.61	19.57	−.04	−.236
	(2.11)	(2.08)		
	340	314		
Cumulative GPA	3.07	3.11	.04	.883
	(.61)	(.54)		
	339	314		
Composite ACT	26.40	27.14	.74	2.83**
	(3.26)	(3.10)		
	298	292		

Note: Cell entries are means, standard deviations (in parentheses), and *N*. *$p < .05$, **$p < .01$, ***$p < .001$.

and demographic variables (ethnicity, sex, age). Descriptive statistics were therefore compiled for each of the three classes to generate a profile of each sample, and appropriate tests for equivalencies between the groups were run to determine whether the control sample varied significantly from each of the treatment samples (Tables 1 and 2).

Independent-samples *t* tests found significant differences only for the composite ACT variable, and this variable was included in the final models to control for effects on the dependent variable (ACS final scores).

Chi-square tests for one of the semester comparisons found a significant relationship between the ACS final and the bivariate variable that coded the difference between White students and students of other ethnicities (see Tables 3 and 4). This variable was included in the final models.

Preliminary bivariate tests were also conducted to gain an initial understanding of the relationship between the exogenous variables and the outcome variables of interest. These tests revealed several significant associations. In particular, being male, being White, and being a science major were all positively associated with scores on the ACS exam (results not shown), and these variables were therefore included in the later regression models to control for their effects on the outcome variables. Age was negatively associated with exam scores and was included in the models as well. Finally, students' composite ACT scores and cumulative GPAs were included in the models due to their likely association with exam performance (ACT, 1998, 2007).

3. Results

3.1. Descriptive statistics

Fifty-five percent of the population taking CHEM 1061 was female, and 45% was male. The mean age of students in the three courses was 19.75 with a standard deviation of 2.5. Eighty percent of students were either freshmen or sophomores; the remainder were juniors, seniors and nondegree seeking students. The demographic data on ethnicity were markedly incomplete. For those on whom we had data, the population was predominantly White at 74%. Sixteen percent identified as Asian, 4% as Black, 2% as Hispanic, and 1% American Indian. The rest were international students and those who specifically chose not to declare their race or ethnicity.

3.2. Initial tests

We began our investigation by comparing Spring 2012 student performance in the traditional class with Fall 2012 outcomes in the ALC. An independent-samples *t* test was conducted using scores on the ACS exam as the criterion variable, and a moderate-sized performance difference was found between the semesters favoring the ALC class, a difference that was statistically significant at the $p < .01$ level (see Table 5). We performed the same analysis on the replicated class held in an ALC in Spring 2013 and found a very small nominal difference in ACS exam scores favoring the ALC class, but this difference was not statistically significant (see Table 6).

3.3. Regression models

Because there were differences between the control class and the two experimental classes on several predictor variables, the bivariate test results cannot be taken at face value. The significant improvement in student performance in fall 2012 and the slight improvement in student performance in spring 2013 might result from the differences in the composite ACT scores and cumulative GPAs of the students in those semesters, for example. Multivariate modeling was therefore conducted to control for the influence of several predictor variables simultaneously. Two multivariate ordinary least squares (OLS) regression models were constructed, one for the initial study and one for the replication, to predict students' performance on the outcome variable of interest in this study.

Table 3
Initial study: Differences between traditional classroom and ALC on ethnicity and sex.

	Traditional classroom (Spring 2012)	Active learning classroom (Fall 2012)	Chi-square statistic	*phi*
White	69.1%	69.3%	.003	.002
	340	339		
Sex	42.6%	43.8%	.757	.012
	340	340		

Note: Cell entries are percentage White/percentage male, and *N*.

Table 4
Replication study: Differences between traditional classroom and ALC on ethnicity and sex.

	Traditional classroom (Spring 2012)	Active learning classroom (Spring 2013)	Chi-square statistic	*phi*
White	69.1% 340	80.3% 314	10.648**	.128
Sex	42.6% 340	47.1% 314	.04	.045

Note: Cell entries are percentage White/percentage male, and *N*. *$p < .05$, **$p < .01$, ***$p < .001$.

The first model compared the control section, spring 2012, with the first flipped ALC treatment section, fall 2012. For this model, casewise diagnostics were generated and examined to locate outliers in the data set, defined as cases with standardized residuals greater than 3.3. This procedure revealed only a single outlier for the dependent variable, and on inspection this case was not otherwise anomalous, so it was retained in the data set. Variance inflation factor (VIF) statistics were also generated to check for multicollinearity among the predictor variables. In no case was the VIF statistic greater than 1.394, far from the common cut-off of 4, so multicollinearity did not appear to be a problem in the data set. The Durbin–Watson statistic of 1.478 indicates only a small amount of positive auto-collinearity in the data.

This model was highly significant ($p < .0001$) and accounts for a moderate amount of the variation in final grades with an r^2 value of .419, adjusted $r^2 = .411$. The covariate, ACT score, was significantly related at the $p < .05$ level to scores on the ACS final ($t = 9.051$, $p = .000$), as were GPA ($t = 8.792$, $p = .000$), sex ($t = 7.314$, $p = .000$), and age ($t = 2.763$, $p = .006$). Being a science major was not a significant predictor, however, nor was being in the ethnicity category White. Finally, the main treatment of interest, section, was significantly related to ACS final scores ($t = 1.978$, $p = .049$).

Given the results displayed in Table 7, we can conclude that for each unit increase in a student's ACT score, we can expect about a 1.5 point increase in that student's ACS exam score. Similarly, for each unit increase in a student's GPA, we can expect a 7.5 point increase in that student's ACS score. The coefficients for the sex predictor variable indicate that on average, while holding other variables in the model constant, male students had ACS scores more than 7 points higher than female students, and that on average, a student who was 1 year older scored about 1 point higher than his or her younger counterpart. Lastly, students in the ALC treatment section scored, on average, almost 2 points higher on the ACS exam than students in the control section, after controlling for the other variables in the model.

Putting these findings in standardized terms, for each standard deviation increase in a student's ACT score, we expect a .371 standard deviation increase in that student's final grade. Similarly, for each standard deviation increase in a student's GPA, we expect a .325 standard deviation increase in that student's ACS score; male students had ACS scores that were an average of .266 standard deviations higher than female students; students who were one standard deviation older tended to achieve ACS results that were .100 standard deviations higher than younger students did; and students in the treatment section had, on average, a .070 standard deviation advantage on the ACS exam.

The second model compared the control section, spring 2012, with the second flipped ALC treatment section, spring 2013. For this model, casewise diagnostics were again generated and examined to locate outliers in the data set, and again only a single outlier was found, which was retained in the data set. VIF statistics indicated very little multicollinearity, and the Durbin–Watson statistic of 1.378 showed only a moderate amount of positive autocollinearity in the data.

This model was highly significant ($p < .0001$) and accounts for a moderate amount of the variation in final grades with an r^2 value of .432, adjusted $r^2 = .425$. The covariate, ACT score, was significantly related at the $p < .05$ level to scores on the ACS final ($t = 9.597$, $p = .000$), as were GPA ($t = 9.996$, $p = .000$), sex ($t = 6.790$, $p = .000$), age ($t = 2.742$, $p = .000$), and being in the ethnicity category White ($t = 2.742$, $p = .006$). Being a science major was not a significant predictor of ACS final exam scores, nor was the main treatment of interest, section ($t = -1.057$, $p = .291$).

Given the results displayed in Table 8, we can conclude that for each unit increase in a student's ACT score, we can expect about a 1.6 point increase in that student's ACS exam score. Similarly, for each unit increase in a student's GPA, we can expect an 8.6 point increase in that student's ACS score. The coefficients for the sex predictor variable indicate that on average, while holding other variables in the model constant, male students had ACS scores more than 6.5 points higher than female students, White students scored about 3.1 points higher than nonWhites, and that on average, a student who was 1 year older scored slightly more than 1 point higher than his or her younger counterparts, after controlling for the other variables in the model.

Putting these findings in standardized terms, for each standard deviation increase in a student's ACT score, we expect a .364 standard deviation increase in that student's final grade. Similarly, for each standard deviation increase in a student's GPA, we expect a .336 standard deviation increase in that student's ACS score; male students had ACS scores that were an average of .236 standard deviations higher than female students; students who were one standard deviation older tended to achieve ACS results that were .135 standard deviations higher than younger students did; and White students had, on average, a .093 standard deviation advantage on the ACS exam.

3.4. Analysis by GPA quartiles

Because technology often affects different segments of a population differently, we analyzed the impact of the shift from a traditional format to the hybrid, flipped format by GPA quartile. With this investigation, we sought to determine whether this shift in format was differentially advantaging or disadvantaging certain parts of the student ability/aptitude spectrum.

Table 5
Initial study: Differences between traditional classroom and ALC on ACS exam.

	Traditional classroom (Spring 2012)	Active learning classroom (Fall 2012)	Difference	*t* statistic
ACS	65.80 (14.10) 304	68.87 (12.73) 275	3.07	2.744**

Note: Cell entries are means, standard deviations (in parentheses), and *N*. **$p < .01$.

Table 6
Replication study: Differences between traditional classroom and ALC on ACS exam.

	Traditional classroom (Spring 2012)	Active learning classroom (Spring 2013)	Difference	*t* statistic
ACS	65.80 (14.10) 304	66.36 (13.64) 316	.56	.86

Note: Cell entries are means, standard deviations (in parentheses), and *N*.

Table 7
OLS regression of exam performance on semester: Initial study.

	Model 1: ACS standardized final exam
Semester (spring 2012 vs. fall 2012)	1.908* (0.965)
ACT	1.527*** (0.169)
GPA	7.479*** (0.851)
Age	1.038** (0.376)
Sex	7.274*** (0.995)
Science major	1.695 (1.239)
White	2.068 (1.175)
Constant	−23.733 (9.346)
N	491
Adjusted R^2	.411
F Test	49.841***

Note: Cell entries are unstandardized OLS coefficients with standard errors in parentheses. *$p < .05$, **$p < .01$, ***$p < .001$.

We divided each semester's students into four groups of approximately the same size based on the students' cumulative GPAs, and we used independent-samples *t* tests to compare the lowest GPA group in the control section, spring 2012, with the corresponding GPA group in each of the treatment sections, fall 2012 and spring 2013, in terms of mean scores on the ACS exam. The results are displayed in Figs. 3 and 4.

As the figures show, it seems that the impact of the change from a traditional to a hybrid, flipped format affected all aptitude/ability segments of the student population approximately equally. For the spring 2012—fall 2012 contrast, we found a 3—4 point advantage for the hybrid-flipped version of the class in the lower three quartiles, and a 1-point advantage in the top quartile. For the spring 2012—spring 2013 contrast, we found small advantages (0.5—2 points) for the hybrid-flipped version in the bottom two and top quartiles, along with a 0.35-point nominal advantage for the traditional version in the second-highest quartile.

None of the differences in either contrast were statistically significant, probably due to the lower per-quartile *N*, and a ceiling effect may explain the finding of somewhat lower gains in the top quartile as compared to the lower quartiles.

3.5. *Student perceptions of the learning environment*

Using our student perception of learning environment survey administered to students on the final day of class, we constructed seven theoretical variables that have shown to be influenced by formal learning spaces: engagement, enrichment, flexibility, effective use, student learning outcomes, room/course fit, and confidence (Walker et al., 2011). The students in the ALCs returned significantly higher scores on all variables except room/course fit, which was still positive, and effective use, which was not significant (see Table 9). In the replication study, students scored the ALC rooms in a similar pattern, though the negative results for effective use were significant, and the ratings for enrichment were slightly negative but not significant. Table 10

4. Discussion

The challenge of these two studies was to find a more efficient way of utilizing classroom space and hence to reduce pressure on that space. The solution tested here yields efficiencies by reducing by 66% the amount of time students spend in the classroom, while leveraging

Table 8
OLS regression of exam performance on semester: Replication study.

	Model 2: ACS standardized final exam
Semester (spring 2012 vs. spring 2013)	−0.947 (0.896)
ACT	1.583*** (0.165)
GPA	8.645*** (0.865)
Age	1.140*** (0.282)
Sex	6.507*** (0.958)
Science major	2.071 (1.194)
White	3.120** (1.138)
Constant	−31.321 (7.732)
N	556
Adjusted R^2	.425
F Test	59.520***

Note: Cell entries are unstandardized OLS coefficients with standard errors in parentheses. *$p < .05$, **$p < .01$, ***$p < .001$.

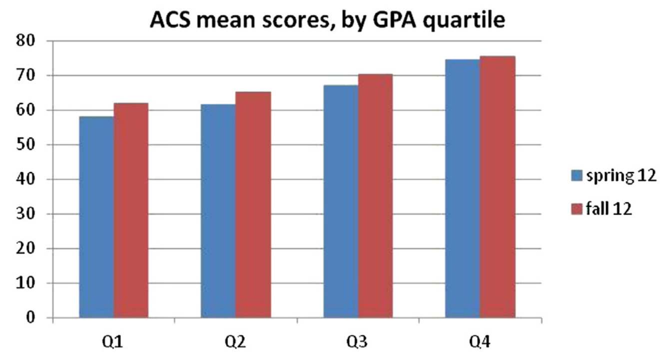

Fig. 3. ACS mean scores by GPA quartile.

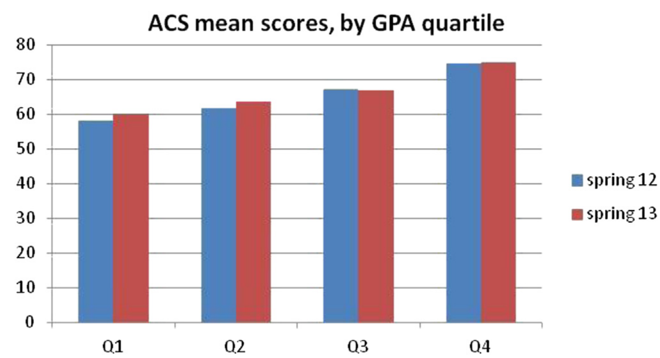

Fig. 4. ACS mean scores by GPA quartile.

three mechanisms that are known to support student learning outcomes and student perceptions of the learning process: (a) blending face-to-face instruction with online materials, (b) flipping the instructional experience so that information presentation is moved online while face-to-face time is used for problem-solving activities, and (c) holding the class in an ALC.

Overall, the results of the two studies presented here show that, after controlling for demographic and aptitude-related variables, flipped, hybrid ALC-based classes can yield student-learning outcomes that are at least as good as, and in one study better than, a comparable class taught in a traditional auditorium-style classroom. An analysis by GPA quartiles showed that the effects of the move to the new format were evenly distributed across GPAs and did not disadvantage students at any particular GPA level.

Furthermore, student perceptions of their learning experience tended to improve significantly with the move to the flipped, hybrid format. The one exception to this trend was the "effective use" construct, on which students in both studies gave significantly higher ratings

Table 9
Initial study: Differences between traditional classroom and ALC on student perception of the learning space.

	Traditional classroom (Spring 2012)	Active learning classroom (Fall 2012)	Difference	Cohen's d	t score
Engagement	2.42	3.06	.64	1.25	12.94***
	(.52)	(.50)			
	203	212			
Enrichment	2.81	2.91	.10	.19	2.01*
	(.54)	(.54)			
	203	216			
Flexibility	2.74	3.11	.37	.63	6.39***
	(.59)	(.59)			
	204	218			
Effective use	3.64	3.55	−.09	.19	−1.85
	(.46)	(.51)			
	207	218			
Student learning outcomes	2.64	2.86	.22	.52	5.26***
	(.42)	(.43)			
	194	213			
Room course fit	3.23	3.33	.10	.16	1.80
	(.59)	(.63)			
	208	215			
Confidence	2.28	2.75	.47	.98	10.13***
	(.49)	(.47)			
	201	213			

Note: Cell entries are means, standard deviations (in parentheses), and N.$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Table 10
Replication study: Differences between traditional classroom and ALC on student perception of the learning space.

	Traditional classroom (spring 2012)	Active learning classroom (spring 2013)	Difference	Cohen's *d*	*t* score
Engagement	2.42	2.94	.52	1.05	10.97***
	(.52)	(.47)			
	203	246			
Enrichment	2.81	2.78	−.03	.06	−.517
	(.54)	(.53)			
	203	247			
Flexibility	2.74	2.96	.22	.38	4.10***
	(.59)	(.56)			
	204	246			
Effective Use	3.64	3.44	−.20	.41	−4.38***
	(.46)	(.52)			
	207	249			
Student Learning Outcomes	2.64	2.81	.17	.38	3.94***
	(.42)	(.47)			
	194	239			
Room/Course Fit	3.23	3.30	.07	.12	1.34
	(.59)	(.56)			
	208	249			
Confidence	2.28	2.66	.38	.78	8.17***
	(.49)	(.49)			
	201	243			

Note: Cell entries are means, standard deviations (in parentheses), and *N*.*$p < .05$, **$p < .01$, ***$p < .001$.

to the traditional class than to the ALC-based classes. We believe this finding reflects the classroom-relativity of the questions composing this construct. Simply lecturing clearly in an auditorium-style classroom might count in students' minds as a very effective use of *that* room, while the evidently greater potential of the ALCs — with their unusual physical layout and technological affordances — raises the standards by which effective use is evaluated. Indeed, effective use of the classroom might be masked if students fail to recognize the transformed role of the instructor from one who lectures to one who delivers problem solving sessions that compel students to actively grapple with key disciplinary constructs.

5. Conclusion

Our research question essentially asked if we could trade contact hours for an active learning pedagogy and environment and achieve the same student experience and learning outcomes. We reduced the total amount of time students spent in the classroom by two-thirds while lectures were shifted online. The reduced classroom time was spent in an active learning classroom where students worked with each other to solve problem sets, answer clicker questions, listen to spot explanations of key concepts, and watch short demonstrations. The students achieved learning outcomes that were in one case superior to, and in the other case statistically equal to, the outcomes from the traditional classroom when measured by a standardized exam, and their perceptions of their learning environment were improved.

Our experimental condition limited the online interaction to a simple lecture capture in order to keep as many variables constant as we could. The blended format, of course, allows for many different types of interactions, and one could further augment the course with the adoption of additional online active learning strategies. For instance, we've observed a Biology course in an ALC use a video message board (Flipgrid.com) to compel students to introduce themselves to their groups and to answer short questions. Recent research has shown that creating *designed interaction treatments* or assignments that intentionally draw students into collaborative situations in an online environment have a positive effect on student learning outcomes (Borokhovski, Tamim, Bernard, Abrami, & Sokolovskaya, 2012). That groups are formed in person should make it easier to design assignments that continue conversations online and echo the social connections formed in the ALC. Cognitive support technology, such as simulations and serious games, have also been found to be significantly effective in a blended environment (Bernard et al., 2014). The transformative potential of the blended classroom has long been noted (Garrison & Kanuka, 2004), and combined with the ALC, this potential might be magnified. For the purposes of this study, though, we recognized that not all instructors have the support to introduce robust active learning activities that can be adequately monitored in an extremely large course, so we limited the instructor's involvement to recorded lectures (Brownell & Tanner, 2012). This suggests that even with limited resources and time, the benefits of a flipped and blended course in an ALC are still measureable and in some instances significant.

This success suggests that we can extend the reach of the limited number and size of the active learning classrooms, because it matters less how much time students spend in class, and much more what they do while they are in class and what sort of classroom they are in. A classroom that was built to serve 126 students can be scheduled for the same number of hours in a semester and accommodate over 375 students. This means that more students can be exposed to these new environments and that the reach of the classrooms can extend well beyond their original design. Indeed, future planners should consider the cost of building new ALCs against not simply a traditional model of using a classroom but also the cost savings that would result from using the classroom in a blended model. As in other studies of redesigned courses, ancillary benefits, such as improved perceptions of the learning space, accompany the potential for cost savings (Graham, 2013).

The blended-ALC course also increases the range of pedagogy in a single course, allowing students to watch lectures individually but also drawing them together in person for guided inquiry and problem solving sessions. Flexibility suggests a range of options. This study reduced face-to-face instruction from 150 min a week to just 50 min. Although we found that learning outcomes were not worsened and count this result a success, we wonder if the learning outcomes might yet be improved with more time in the ALC. Would a 75-min-per-week session prove superior to the 50-min sessions we tested? Indeed, is there an optimal amount of exposure to an ALC that provides the greatest learning benefit to a student?

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