

Space matters: The impact of formal learning environments on student learning

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Abstract

The objective of this research is to identify the relationship between formal learning spaces and student learning outcomes. Using a quasi-experimental design, researchers partnered with an instructor who taught identical sections of the same course in two radically different formal learning environments to isolate the impact of the physical environment on student learning. The results of the study reveal that, holding all factors excepting the learning spaces constant, students taking the course in a technologically enhanced environment conducive to active learning techniques outperformed their peers who were taking the same course in a more traditional classroom setting. The evidence suggests strongly that technologically enhanced learning environments, independent of all other factors, have a significant and positive impact on student learning.

Introduction

The subject of learning spaces has engendered a host of conversations that occur at the intersection of the design of physical spaces, the appropriate technology with which to populate newly configured spaces and the impact such spaces have on how faculty teach and students learn in them (Lomas & Oblinger, 2006; Montgomery, 2008; Oblinger, 2006). Given the nascent character of this field of study, scholars and practitioners have been engaged in a concerted effort to develop theoretical models, to formulate a common terminology, to encourage rethinking pedagogical approaches and to develop effective assessment and evaluation tools related to learning spaces (Hunley & Schaller, 2009; Jorn, Whiteside & Duin, 2009; Lippincott, 2009; Long & Holeyton, 2009). For all that has been written on the subject however, there is a dearth of systematic, empirical research being conducted on the impact of learning spaces on teaching and learning outcomes.

In an attempt to correct this lack of evidence, researchers from the Office of Information Technology (OIT) at the University of Minnesota partnered with faculty members and undergraduate researchers to collect data on the relationships between formal learning spaces, teaching and learning practices and learning outcomes. The parameters of the study afforded researchers the opportunity to undertake a quasi-experimental research design in which numerous variables were controlled to isolate the impact of the physical spaces on student learning. Our results demonstrate clearly that the formal physical environment in which students take their courses has a significant impact on measurable student learning outcomes.

Literature review

The relatively embryonic study of learning spaces has garnered considerable academic and institutional attention to the impact of physical space and its accoutrements on student learning and faculty pedagogy. So important is this topic that Educause, a leading organisation for promoting technological advancements in higher education, recently devoted nearly entire issues of their most prominent publications to the subject. Advocates of designing and redesigning spaces that are more conducive to learning claim that benefits to teaching and learning practices and outcomes outweigh the short-term costs by promoting constructivist forms of active learning, encouraging pedagogical innovation, improving conceptual, theoretical and applied forms of learning, and increasing overall levels of student engagement. Despite the considerable theoretical and practical attention the topic has received, very little empirical research has been conducted to evaluate these claims.

In addition to the current learning space research being conducted at the University of Minnesota, a literature review revealed only two other major projects that have produced research that explores the effects of learning environments on teaching and learning. The first of these is North Carolina State University's Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP), the development of which began in the 1990s to transform the manner in which calculus-based introductory physics courses were taught. The SCALE-UP space employs large round tables for students, laptop connections and projectors that can be used to share student work, access to laboratory equipment for in-class experimentation and student microphones. In addition to the space redesign, the pedagogical approach and teaching materials were completely overhauled to improved cooperative learning, enhance in-class problem solving, and increase faculty-student interaction. The impact of these modifications to course design and formal learning environments is manifested in a number of ways including increased levels of conceptual understanding, especially among the top tier of students, improved problem-solving skills, attitudes and class attendance rates and a reduction in both the overall and at-risk student failure rates (Beichner *et al.*, 2007).

The second major project yielding empirical results in support of learning environments' impact on educational outcomes is the Massachusetts Institute of Technology's Technology Enabled Active Learning (TEAL) project. The TEAL project focuses on employing software-based simulations and visualisations in an active learning environment designed to facilitate student interaction and problem solving in a first-year physics course. Similar to the SCALE-UP project, TEAL incorporated a redesign of both course approaches and the space in which the course is held. Courses now emphasise hands-on experimentation, technological visualisations and demonstrations and other collaborative active learning techniques; the classrooms were configured with round student tables, laptop connections, display screens and marker boards around the circumference of the room. Lacking the randomisation of subjects (Pedhazur & Schmelkin, 1991), TEAL researchers employed a quasi-experimental design and found that students in the TEAL programs had lower failure rates and higher rates of conceptual understanding than students taking the course in a traditional environment with a lecture-based approach (Dori *et al.*, 2003).

While the findings from these projects are extremely important in bolstering empirically the claims advanced by proponents of new learning spaces, both suffer from methodological issues that limit their effectiveness in discerning the relationship between space and student learning outcomes. In general terms, none of the research designs in the above-noted projects sufficiently control for a number of confounding factors that might obscure the relationship between space and learning. Specifically, both studies employ historical designs that compare several iterations of *similar* courses over an extended period of time and that cannot account for a host of exogenous factors related to student body composition and endogenous factors related to differences in instructor approach. The lack of controls is especially evident in the TEAL project where new

materials and visualisations are added continuously during the project thereby changing the actual substance of what students learn; the comparably large number (up to eight) of instructors introduces considerable variation in terms of pedagogical approach, teaching style and content that raises questions about cross-sectional comparability; and the differing assessment methodologies for 'experimental' and control groups compromises the integrity of claims (Dori & Belcher, 2005).

Finally, since both the SCALE-UP and TEAL projects each entail comprehensive course redesign and new active learning environments, there is no way to know whether or not the results garnered from their studies are due to course redesign, classroom design or both. If we are to understand more fully the impact of the physical aspects of formal learning environments, a more systematically rigorous research design is necessary to place controls on potentially confounding factors. The research conducted by the OIT research team at the University of Minnesota makes significant progress in this direction.

The OIT research team began its research on the impact of learning environments on teaching and learning in fall 2007. Funded by a grant from the Archibald G. Bush Foundation, the pilot study gathered data from faculty and students who were involved in courses taught in the University of Minnesota's Active Learning Classrooms (ALC). The ALCs, which are modelled on the rooms created as part of the SCALE-UP and TEAL projects, are designed with an emphasis on innovative and flexible construction that can accommodate new course designs and encourages new pedagogical approaches. Specifically, the two ALCs presently in use at the University of Minnesota feature large, round tables that accommodate up to nine students each, switchable laptop technology that allows students to project content onto flat panel display screens linked to their respective tables, an instructor station from which content is displayed to two large projector screens and feeds to the student display screens are controlled and wall-mounted glass markerboards around the perimeter of the room (University of Minnesota Active Learning Classrooms Pilot Evaluation Team, 2008; Whiteside & Fitzgerald, 2009).

The results of the pilot evaluation of the ALCs were overwhelmingly positive. In general, both students and faculty perceived the ALCs as useful for changing the manner in which they learned and taught, respectively. Furthermore, both groups reported differences in the relationships between faculty and students and among students as a result of the ALC environment. Of the innovative features of the ALC, the round tables were frequently cited as the most important feature of the space because they lent themselves to a greater use of collaborative and student-centred learning activities (University of Minnesota Active Learning Classrooms Pilot Evaluation Team, 2008; Whiteside & Fitzgerald, 2009).

In fall 2008, the OIT research team partnered with three faculty members who were teaching courses in the ALC spaces to collect data to evaluate empirically the extent to which formal and informal learning environments shape teaching and learning practices and student learning outcomes. Given the need to evaluate systematically a number of testable hypotheses related to this larger research question, we employed a variety of data collection methods (eg, faculty interviews, student focus groups, class observations, student surveys, student assignment logs, photo surveys) that were supplemented with institutional and course-level data on students enrolled in the courses in question. The scope of the project and the diversity of subjects included in the study proved conducive to employing multiple research designs such as single group pre-post measures, qualitative case studies and a quasi-experimental design. It is the latter of these from which the findings presented here are drawn.

We were able to employ a quasi-experimental design for the Postsecondary Teaching and Learning (PsTL) 1131: Principles of Biological Science course given that two sections of the course were offered with one section taught in a traditional classroom (ie, whiteboard, projection screen

Table 1: Summary statistics for PsTL 1131 (all students)

	n	Mean	Standard deviation	Minimum	Maximum
ACT	83	21.52	4.16	12	30
Grade	86	491.86	61.49	283.78	581.51

and instructor desk at the front of the room, student tables facing the front of the room, etc.) and another taught in an ALC. This arrangement allowed researchers to control for numerous potentially confounding factors thereby isolating the relative impact of the ALC environment on teaching and learning. In terms of controls, or factors that we tried to keep constant, both sections of the course were offered during an 8:15–9:55 a.m. time slot with the traditional classroom meeting on Mondays and Wednesdays and the ALC classroom meeting on Tuesdays and Thursdays. The instructor used the same course materials, assignments, schedules and exams for both sections and made considerable efforts to keep his approach to delivering course material the same in each section. Although the randomisation component required to make the design fully experimental was absent from the study as students were automatically enrolled into their lecture sections based on the laboratory for which they registered, the only demographic characteristic of students that was significantly different across the sections was the composite ACT score. The only factor that was allowed to systematically vary across the sections was the type of formal learning space in which the course was being taught.

Data

Given that the overwhelming majority of students who registered for PsTL 1131 in fall 2008 were first semester, first-year students, the only consistent and standardised measure of students' academic ability available was their composite ACT scores. ACT scores have been demonstrated to be reliable and valid predictors of grades, especially among first-year college students, typically predicting approximately 20% of the variation in student grades (ACT, 1998, 2007; Marsh, Vandehey & Diekhoff, 2008; Stumpf & Stanley, 2002; Wilhite, Windham & Munday, 1998; Ziomek & Andrews, 1996). The average ACT score for all students enrolled in PsTL 1131 was 21.52 with a standard deviation of 4.16 (See Table 1).

The second variable of interest to this study is course grade. The course grade for PsTL 1131 was calculated as the sum of points earned by students on various assignments that included class participation, a special group project, a midterm exam, a final exam and a laboratory grade. The average number of points earned by students enrolled in PsTL 1131 was 491.86 with a standard deviation of 61.49.

Analysis

As mentioned previously, the only exogenous variable for which we obtain statistically significant differences is the ACT variable. For the PsTL 1131 section that met in the traditional classroom, the ACT scores have a mean of 22.54 and a standard deviation of 4.38. The section that met in the ALC has an average ACT score of 20.52 with a standard deviation of 3.72. The difference of means between the traditional classroom section and the ALC section is 2.01, a difference that is statistically significant at the $p < 0.05$ level (see Table 2).

Given the known relationship between ACT scores and grades, we would expect the students in the traditional classroom to have a statistically significant higher grade than their peers in the ALC by the end of the semester. Specifically, based on ACT scores, we would expect the students in the ALC to earn an average of 454.58 points while the students in the traditional section would earn 502.19 points, a difference of 47.61 points. It is therefore reasonable to expect that the null

Table 2: Difference of means tests of ACT scores and course grades, by section

	Traditional classroom	Active learning classroom (ALC)	Difference
ACT composite score	22.54 (0.68) 41	20.52 (0.57) 42	2.01*
Grade	499.33 (9.13) 43	484.39 (9.59) 43	14.94

Note: Cell entries are means with standard errors in parentheses and the number of cases.
* $p < 0.05$.

hypothesis—that there is no difference in the average course grade of the traditional classroom compared to the average grade for students in the ALC—should be rejected. However, a standard difference of means test of the course grades by section, in fact, reveals the opposite (see Table 2). The students in the traditional classroom earned an average of 499.33 points while the students in the ALC earned 484.39 points, a difference of 14.94 that is not statistically significant ($p = 0.26$). That is, despite what their ACT score should have predicted, students in the ALC earned statistically the same grade as their peers in the traditional classroom.

To put it another way, students in the ALC both exceeded expectations of their own grades as predicted by their ACT scores and outperformed their peers in the traditional classroom. Regarding the former point, the ALC students earned an average of 29.81 more points than expected, a result large enough to render the difference between them and traditional students' average grade statistically insignificant. On the latter point, for students in the ALC, the average difference between their expected and actual grades was approximately 11.5 times larger than the average difference between expected and actual grades for students in the traditional classroom (Figure 1).

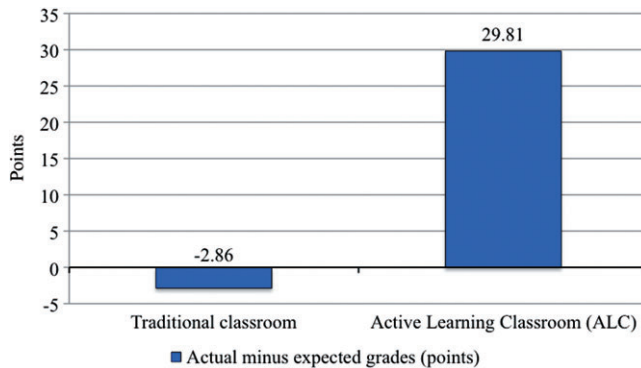


Figure 1: Difference between actual and expected course grades, by section

These findings are remarkable given three basic factors inherent to the data. First, despite a lack of randomisation of students into their respective sections, there were no significant differences on any exogenous characteristics (eg, demographics) between students in the traditional classroom and the ALC, except their composite ACT scores. Second, the only other factor that was allowed to vary was the type of classroom in which the sections were taught. And, third, there is no statistically significant difference between the final grades earned by students in either section.

Table 3: OLS regression of ACT score on course grade, by section

	Model 1: traditional classroom	Model 2: active learning classroom (ALC)
ACT composite score	9.34** (1.67)	7.42* (2.30)
Constant	291.67** (38.42)	334.92** (48.04)
Adjusted R ²	0.42	0.19
N	41	42

Note: Cell entries are standardised OLS regression coefficients with standard errors in parentheses.
* $p < 0.01$, ** $p < 0.001$.

Thus, we must draw the conclusion that the students who took PsTL 1131 in the ALC and who had significantly lower ACT scores learned at a higher rate than their traditional classroom counterparts as a result of factors associated with the environment of the ALC.

To our knowledge, this is the first piece of empirical evidence that demonstrates that space, and space alone, affects student learning. However, the affordances of an active learning environment that allows students to outpace their peers in more traditional settings may have the unintended consequence of undermining established predictors of student success, such as ACT scores. In order to evaluate the impact of space on the relationship between ACT scores and grades, for data from each section, we employ a linear regression model of the following form:

$$\text{GRADE} = \beta_0 + \beta_1 \text{ACT} + \varepsilon.$$

While the null hypotheses tested by this model is that ACT scores do not significantly predict students' final course grades, the literature suggests that we should expect ACT scores to have a significant and positive impact on student grades. Controlling for other factors, if ACT scores fail to predict course grade either significantly or positively, the evidence would suggest that the physical space is responsible for disrupting the expected relationship between a student's aptitude and her learning outcomes.

Model 1 contains the results of the regression model for the section of PsTL 1131 held in the traditional classroom setting (see Table 3). Here, we reject the null hypothesis that ACT scores do not significantly predict students' final course grades. This means that, as expected, in the traditional learning space, ACT scores are good predictors for course grades. Specifically, for students enrolled in the traditional classroom section, every one (1) point increase in ACT score leads to a 9.34 point increase in course grade, a relationship that is highly statistically significant ($p < 0.001$). However, the adjusted R^2 of 0.42 is particularly noteworthy given that (1) a single variable predicts two-fifths of the variation in the dependent variable and (2) it indicates that the amount of variation in a student's grade predicted by ACT score is approximately two times what such a model would normally predict. Holding all other things constant, this suggests that a traditional classroom setting enhances significantly the predictive power of ACT scores.

The second model, for the section that convened in the ALC, produces similar results. Again, we reject the null hypothesis that ACT scores are not significant predictors of student grades. For students enrolled in the ALC section, for every single point increase in ACT scores, grades increase by 7.42 points, a coefficient slightly lower than for the traditional section but significant at the $p < 0.01$ level. Furthermore, the adjusted R^2 of 0.19, which is more comparable to scores in the literature, reveals that for students in the ALC, ACT scores predicts approximately 50% less

variation in the final course grade than in the traditional classroom. Therefore, we conclude that the ALC has a significantly positive effect on student learning without undermining the reliability of ACT score as a predictor of student learning.

Given the controlled parameters of the quasi-experimental design by which these data were produced, these findings are the most robust produced to date that suggest that learning spaces have a significant effect on student learning. The strong evidence of the positive impact of space on student learning however, only scratches the surface of the research that needs to be carried out in the field of learning spaces.

Conclusion

As the study of learning spaces remains in its infancy, considerable work remains to demonstrate empirically the impact of formal learning spaces on student learning outcomes and practices. The findings here contribute significantly to this discussion given that they are the first to demonstrate that controlling for nearly all other factors, physical space alone can improve student learning even beyond students' abilities as measured by standardised test scores. This overcomes the limitations of previous research on the subject, which had obscured the effects of the physical space by combining redesigns of learning spaces with comprehensive curricular revisions.

The findings presented here advance considerably the field of learning spaces research. However, many questions remain regarding the relationship between formal learning spaces and teaching and learning including, but not limited to, the following: (1) What characteristics of formal physical spaces contribute to the accelerated pace of learning in an ALC?; (2) How do the formal learning spaces affect students' perceptions of their learning experiences?; (3) Do students respond differently to the contributions of formal learning environments based on demographic characteristics, course level, or subject matter?; (4) How does the space constrain or facilitate faculty teaching practices and behaviours?; and (5) How does variation in those practices and behaviours caused by variation in formal spaces shape student engagement? With the data collected as part of the OIT Learning Spaces Research project, we hope to have answers to these questions in the very near future.

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