AC 2010-1266: ENGAGING SPACES FOR FIRST-YEAR ENGINEERING: A TALE OF TWO CLASSROOMS

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Engaging Spaces for First-year Engineering: A Tale of Two Classrooms

Abstract

Engaging students in learning through the use of active and cooperative approaches has been recognized as an effective way to improve their educational experience. These approaches are particularly important in the first year where student engagement is an important factor in students success and retention. Engineering education has used these approaches in laboratories, problem sets and projects outside the classroom. The need is to use them more inside the classroom. In spite of this recognition and many faculty who do use these approaches in class, most university learning spaces are designed to be optimized for straight lecture. Active and cooperative processes can be brought into any space but why not design the space with them in mind? Learning spaces of a different design send a message to both faculty and students that a different approach to learning is expected.

Two classrooms were redesigned to easily accommodate active and cooperative approaches in first-year classes. The first room was a computer classroom. It was previously arranged in a traditional configuration where each student had a computer arranged in rows facing the front of the classroom. This space was rearranged to a workshop configuration, where the rows were turned perpendicular to the front. This allows for easier interaction between students and faculty and allows the faculty to easily scan the majority of student computer screens.

A second classroom received a more extensive renovation. It was adapted to accommodate students working in groups on a wide range of activities including discussion, computer work, laboratories, and lecture. This multimodal classroom space is designed around four service clusters that each includes two computers, electrical power, air and water supplies. Each cluster accommodates six students that can be easily broken into groups of two, three or six students. These are both modest sized spaces with capacities of 24 and 28 respectively. However, the space concepts used can easily be applied to larger classrooms.

These spaces were assessed using a behavioral instrument (the Student Classroom Engagement Questionnaire), student comparisons to other facilities, and faculty observations. Active and cooperative learning approaches can be carried out in any learning space. However, learning spaces can be designed to facilitate and encourage these activities. Students report greater interaction with each other and with faculty in these specially designed spaces relative to other learning spaces they use. The Multimodal Classroom allowed the implementation of a new project in one course that increased student time on group tasks in the classroom and significant use of the room outside of class.

Introduction

Many studies have recognized the benefits of using alternative approaches to lecturing in presenting undergraduate material. Students can be more engaged in the material through active, cooperative and inductive approaches. Felder, et. al. in their review paper on "Teaching Methods that Work" discuss seven themes that have repeatedly been shown contribute to student learning.[1] Four of these themes directly relate to the instructors approach in the classroom: establish relevance of course material and teach inductively, balance concrete and abstract information in every course, promote active learning in the classroom, and use cooperative learning. These themes can be emphasized in any learning space. However, a space that is set up with them in mind can facilitate and encourage their use.

In 1986, Chickering and Gamson, with support from a range of colleagues and organizations published the "Seven Principles for Good Practice in Undergraduate Education".[2] Their seven principles are listed below, as worded in a later paper.[3]

Good practice in undergraduate education:

1. encourages contact between students and faculty,
2. develops reciprocity and cooperation among students,
3. encourages active learning,
4. gives prompt feed back,
5. emphasizes time on task,
6. encourages high expectations, and,
7. respects diverse talents and ways of learning.

These principles encourage an approach that is more interactive than a traditional lecture. Such a class would include: cooperative learning exercises that have students working together, easy interaction between the faculty and the student, and the use of diverse approaches to learning. Engineering has long focused on activities that make emphasize these practices with laboratories, regular problem sets, and open-ended group projects. These activities are usually completed out side of the classroom. There is an opportunity to improve the educational experience of our students by bringing more of these activities into the main classroom setting.

Often students and/or faculty resist the change to something other than traditional lecture. Traditional lectures were the way many of us faculty learned and they are still a comfortable mode that does not demand too much of the students. How can we encourage our students and faculty to consider new and alternative modes of instruction? Buckmister Fuller noted "Reform the environment; stop trying to reform the people. They will reform themselves if the environment is right."[4] One option for encouraging greater use of the seven principles is to transform our classrooms so that they more easily accommodate these differences. Ten years after Chickering and Gamson published the Seven Principles, Chickering and Ehrmann[2] noted that we could use "technology as a lever" to help implement these principles. Their article primarily focused on technologies used outside of the traditional classroom. However the technology and setup inside the classroom can help encourage the use of these seven principles.

Experiments are an excellent way to provide concrete particulars to begin inductive learning.[5] Hesketh, Ferrell and Slater[6] recommend the following sequence in using experiments in inductive learning:

1. Prelab Handout - Students are given a handout to peak interest that asks them to hypothesize about qualitative outcome.

2. Data Collection – Students complete experimental work consisting primarily of data collection with graphical analysis.
3. Discussion – Students identify key patterns and experimental relationships.
4. Lecture – Students are presented with key quantitative relationships.
5. Homework – Students are asked to complete calculations based on the laboratory data

Four strategies for bringing experiments into the classroom was outlined by Moor and Piergiovanni.[7] Three of these strategies can be done in a traditional classroom with varying ease depending on the exact learning space. However, the fourth is to change the design of our classrooms to allow experiments to be part of the classroom learning experience.

Active and cooperative approaches can be used in a traditional classroom to increase the effectiveness of instruction. However, in many cases the classroom can make such approaches harder or easier. Some classrooms separate students and can make cooperative approaches difficult. Other classrooms have limited desk space for activities that might require such room. Often the classrooms have been designed for a purpose completely different from the current use.[8] North[9] describes a case, all to common in higher education, where the quality classrooms versus the quality of meeting rooms indicates we value meetings more than classes. A classroom designed with active and cooperative learning approaches in mind can encourage and facilitate their use and display our commitment to the educational process.

Context

This effort was carried out at a regional state university that serves predominately commuter students. A significant number of the students are the first in their family to go to college. Approximately 60% enter the college needing to take one or two semesters to get to Calculus 1. For these latter students they will spend three or four semesters completing their first-year requirements. A large fraction of these students work off campus.

The first-year engineering program includes four engineering courses:

1. Introduction to Engineering - A one-credit introduction to being an engineering student. It has no prerequisites. The course includes student success topics, an introduction to various engineering disciplines and a hands-on group project.
2. Computer Aided Design - A two-credit CAD course.
3. Engineering Computer Tools – A two-credit course that introduces students to using a computer to solve problems. MATLAB is the primary tool used with some work in Excel. Students are introduced to calculations, vectors, files, structured programming and some simple statistics. Students must be calculus ready to take this course.
4. Introduction to Engineering Design – A three-credit project based course that introduces students to an engineering design process and tools for completing the various stages of design. Calculus-based physics is a corequisite for this course.

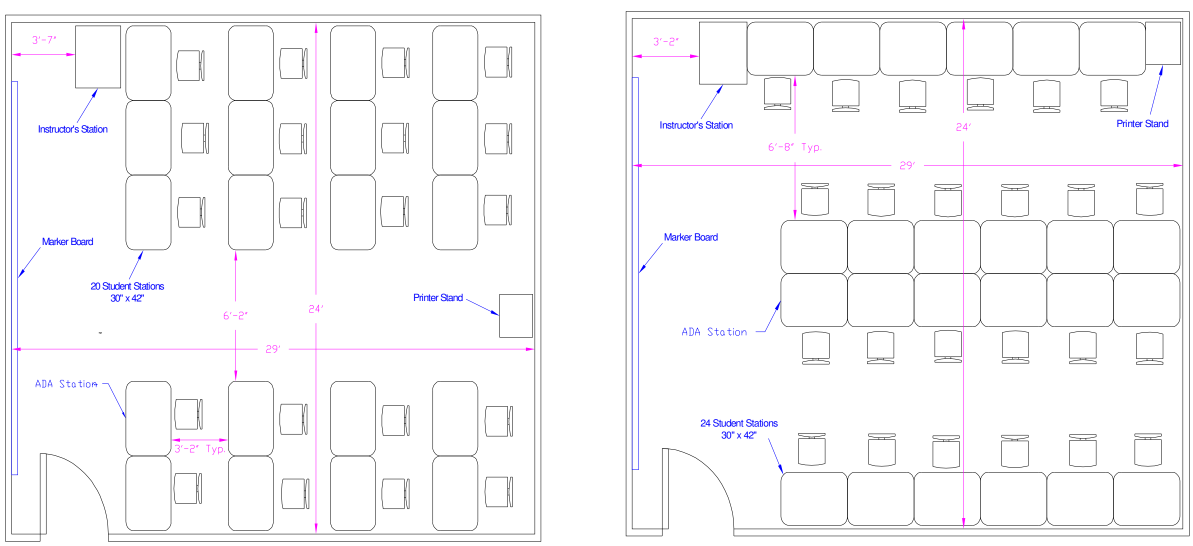
It is unusual to have some many low credit courses in a program but the flexibility of such a setup helps to accommodate diverse situations of the students.

Introduction to Engineering (1 above) and Introduction to Engineering Design (4 above) were formerly both taught in registrar-assigned classrooms which could be of any type and anywhere on campus. This included having the class in large lecture halls or other classrooms where the only desk space was arm desks for taking notes. These classrooms made bringing special activities, particularly hands-on activities, difficult to bring into the classroom. Using computers in the classroom was impossible.

The Computer-Aided Design course (3 above) and the Engineering Computer Tools class were taught in our computer classroom. This room took this traditional form with all rows facing front with computer system units on desktop between students. Figure 1A shows the previous layout of the classroom where the front of the classroom - with white boards, projector screens and instructor station - was on the left side of this floor plan. In this classroom instructors did give brief presentations of material and then students would do some simple exercises. This arrangement has several disadvantages:

1. It is difficult for instructor to quickly see how well students were doing on exercises.
2. It is difficult to reach students down the narrow rows.
3. The system units on the desks tended to prevent student interaction for cooperative learning exercises.
4. Students feel shielded by their computers and are therefore more likely to use the computers for web surfing and other activities unrelated to the class.

This arrangement fit a maximum of twenty students.



(A) Original Classroom Arrangement (B) Renovated Workshop Arrangement

Figure 1: Computer Classroom Arrangements – this classroom was changed from a traditional everyone facing forward (A) to a workshop arrangement with students sitting perpendicular to the front of the room (B).

To improve the learning space for our students two rooms were renovated: 1.) a formerly underutilized room converted to a Multimodal Classroom/laboratory and 2.) a computer classroom converted to workshop style arrangement. These two rooms are next to each other and adjacent to the Engineering Department office suite.

Goals

The key goals for both facilities include:

- Multimodal Education: to provide for multiple modes of education in the same space with a particular emphasis on active and cooperative modes,
- Space Attachment: to encourage students to identify with our program and develop an attachment to the engineering department space,
- Showcase: to be a showcase for recruiting and retention in our program, and
- Informal learning space: to provide an informal learning space when not being used by classes eventually to be available 24/7. (The room access control to accomplish this 24/7 goal is not yet implemented.)

Multimodal Education: These rooms were designed to provide spaces which allow seamless movement between lecture, problem-based learning, simulation, computer work and group exercises. For the computer laboratory student activities needed to include working on individual computer problems. For the Multimodal Classroom student activities needed to include the possibilities of simple laboratories. A physical environment was desired that would:

1. encourage and facilitate greater use of hands-on/minds-on and collaborative forms of learning by instructors.
2. encourage interaction between students and the faculty
3. encourage reciprocity and cooperation between students
4. prepare students for a different type of leaning by the look of the room when they first enter.

The key goal multimodal classroom is the first item in this list, a room that was designed from the ground up with active and cooperative learning approaches in mind. While the computer classroom already did some of this first goal by the simple presence of the computers, its effectiveness could be enhanced. The next two are directly from Chickering and Gamson's "Good Practices in Undergraduate Education" and are related to the first. This is the area that the computer classroom particularly need work; Breaking down the barriers between students and between students and the instructor. It was hoped that these rooms would allow this greater engagement by students with each other, with the instructor and with the material.

The likely function of a space is suggested by the "substances (glass, steel, wood) and surfaces (tables, walls, floors)" present when the student enters the room.[10] This suggestion effects student preparation by informing their attitudes and expectations of what they will be doing. It is desired that these rooms, by their look, would prepare students for an active and cooperative classroom experience.

Space Attachment: These rooms are part of an effort to increase students' sense of identification with the engineering program via experiencing some attachment to the place and by having a place where they come in regular contact with students and faculty in the engineering program. Graetz and Goliber[10] note "As people live and work in physical settings, they may develop a strong connection to a particular location that goes beyond simple preference." As a largely commuter campus students do not easily connect to the university or the engineering program.

We wanted to aid their connection to the program through the places where they study engineering.

Showcase: An additional goal is that these facilities showcase some of the strength of our program. As a regional branch campus of a large state university it is easy for our program to be viewed as a derivative of the main campus program. It was desired that visiting students (tours, outreach …) will have a positive impression of the strength and uniqueness of our program and that continuing students will take pride in their program.

Informal learning spaces: Both of these learning spaces are intended to be available to students for study when they are not being used as classrooms. Eventually, an access control system for the multimodal classroom is planned that will allow for 24/7 access to this space. Classes are scheduled to minimize the time where both rooms are being used as classrooms so there is almost always an informal learning space available in our department.

Multimodal Classroom/laboratory Design: An existing 24 x 30 foot room was converted into this new learning space. Figure 1 shows the floor plan for this new facility and Figure 2 shows two photographs of this facility. The central feature of the room are four work clusters designed to accommodate six students each with the possibility of squeezing one extra student in each cluster if needed. Each cluster has a center trapezoidal service island surrounded by three standard trapezoidal tables for student work. The trapezoidal tables, on locking casters, are generally in the configuration show in Figure 1 but can be rearranged as needed for different classroom activities.

Each cluster has two computers in the central service island. The computer monitors are on articulated arms so that they can be easily repositioned. Computer USB, sound and serial ports are brought up to a patch panel at the desk top for easy use. Standard 110 volt power is also available at the desktop. On the front side of the clusters are hot water, cold water, compressed air and drainage available for conducting simple experiments. This center service island is necessarily fixed to accommodate these services. In the front of the classroom are master shut-off switches for the water and compressed air.

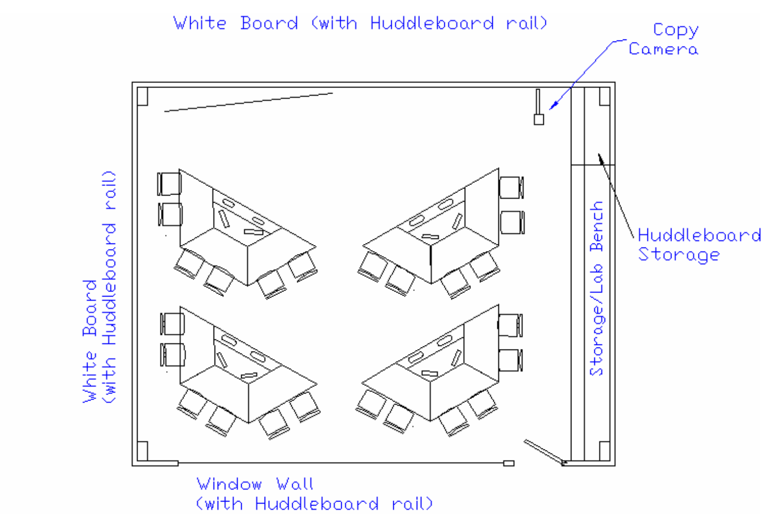


Figure 2: Floor plan for new classroom consisting of work clusters for six students each.

Figure 3: Two views of the new learning space. The picture on the left is from the doorway and the picture on the right is from the front of the classroom.

All four walls are designed to be useful parts of this environment. The front and left side wall are covered in white board to allow ample space for instructor or students use. Also twelve Huddleboards, lightweight portable white boards, are available and used primarily by student groups. These boards can be hung along any of the walls in the room. The right wall is a storage and preparation bench. The back of the classroom is a window wall open to the hall which both opens up the environment inside the room and displays this facility to visitors.

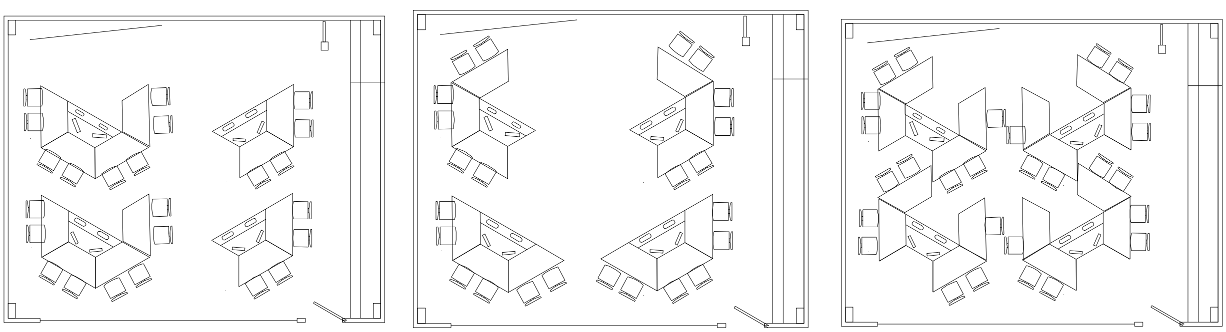
There is a tablet computer for the instructor to use for presentations. The tablet links wirelessly to a classroom server that is connected to the internet and to the classroom projector. All computing happens on the server computer with the tablet acting as a terminal. The tablet allows instructors to present from anywhere in the room and to also to annotate their presentations as they go. All monitors and the classroom projector are wide (16:9) screens. The projection screen is to one side of the room (see Figure 2) allowing instructors to use both projection and the whiteboard at the same time. The room was designed so that the lights can remain on during projection to enhance the interaction in the class. This is accomplished by having a separate switch to turn off the light directly in front of the screen and by having a suitability bright projector.

This set up easily adapts to a variety of instructional approaches and is particularly suited to cooperative learning. Students are grouped in clusters of six that are turned in toward each other by the use of trapezoidal tables. They can be easily broken into groups of two, three or six. Groups of three are natural for computer work. With a slight rearrangement of the tables groups of four can also be used. The Huddleboards are a nice option for group brainstorming or problem solving activities. When gathering students together after they have been in small groups, the Huddleboards can be hung up and students can directly observe each others work.

In addition to handling laboratories, group processes, and computer/simulation activities this classroom also easily accommodates presentation. Students all have good sightlines to the front of the classroom and the instructor has both projection and white board space available. This makes the room less threatening to faculty new to cooperative and active learning approaches. In addition an instructor can move from mini-lecture, to laboratory to group exercise with minimal time for change over. This facility is experimental so many of its features are still being developed.

While this classroom shares many characteristics with some of collaborative and studio classrooms it has a unique combination of features. The base configuration in Figure 1 allows for collaborative learning, lecture presentation and discussion to happen in a single setting. This space also allows for simple experiments to be conducted in this base configuration. The set up allows for easy transition from one activity to another with little transition time.

In addition, the trapezoidal work tables to be rearranged if desired making it a very flexible setup. Figure 3 shows three possible rearrangements that allow for 1) six teams of four students each (instead of the eight groups of three in the base arrangement), 2) the whole class turned in to discuss and/or follow a demonstration in the center of the class ,3) a focused laboratory setup for 3 or 4 students per group to carry out more extensive laboratory experiments. The first two reconfigurations require that only two tables be moved. The last setup uses four additional tables and is shown with 28 chairs.



(1) Groups of four (2) Whole class activity (3) Special Laboratory Setup

Figure 4: Three alternative arrangements of the trapezoidal tables – (1) Allows for groups of four students each, (2) faces the entire class in for full class activities and (3) is a set up for classes that are completely laboratory in nature.

It is a common practice in more innovative learning space design to make the space completely flexible with movable tables and chairs. This approach can run into a couple of problems. Particularly it is easy to rearrange the furnishings back into a traditional arrangement and this is often what happened. On a recent visit to an innovative science learning center with approximately five excellently designed flexible classrooms it was noted that four of the five were arranged in the traditional all rows facing front arrangement and the only one that was not in that arrangement was being used for a teaching seminar. This can diminish the room's ability to encourage faculty to try out more collaborative and active approaches. In addition, flexible furniture rooms often get the complaint that the instructors need to rearrange the furniture every time they teach because of the "weird arrangement" some previous faculty used. The approach used in this space where there are fixed centers that define a base setup but movable tables that allow for rearrangement provides flexibility while addressing these two potential problems.

Computer Classroom Design – A Workshop Arrangement: The computer classroom was changed from its classroom configuration, with all rows facing front to a workshop arrangement where the student desks were perpendicular to the front. This original and new arrangement is shown in Figure 1. Computer system units were moved under the desks to improve sight lines and allow students to more easily interact. Flat panel screens are also used minimizing obstruction of sight lines. In addition, a new classroom network was installed in the classroom. This new set up:

1. allows for the instructor to easily circulate among the students using the two new larger isles,
2. allows the instructor to easily scan three quarters of the monitors in the classroom from one position and to scan all monitors from the front of the classroom,
3. allows for cooperative learning exercises with out barriers between students,
4. removed student anonymity and therefore discouraged improper use of the computers
5. increased capacity of the classroom from twenty to twenty-four students reducing the number of sections that need to be offered each year,
6. improved quality of instructor control of the classroom computers and projection through the upgraded classroom network system, and,

When not being used as a classroom it serves as the main open computing laboratory for the entire Department of Engineering. In addition it provides the School of Engineering, Technology and Computer Science with a computer classroom designed for active learning.

The aesthetics of the room were also improved. A wire raceway surface is mounted on the walls is used to run the power and network cables. In the original classroom this raceway was an industrial gray metal that made the room look like a factory floor. During renovation vertical runs of the raceway were painted the same as the wall they were mounted on so that they blended in. While the horizontal run were painted to form an accent strip in the room’s color scheme.

This classroom is equipped with a classroom network that allows the instructor control of all the computers in the room. A “Mobil Hybrid Link System” (Applied Computer System, Inc., Johnstown, OH) was purchased for this purpose. This system includes the ability for the instructor to:

- blank all or some of the screens in the room,
- send the image from the instructors computer to all or some of the screens in the room,
- send the image from any student computer in the room to the projector, the instructors monitor, or to all the other screens in the room,
- take over the keyboard and mouse of any machine in the room, and,
- pose questions for the students to respond to.

These abilities help the instructor structure and run their classes. The ability to transmit to every screen in the room can be used when longer presentations are given so students do not need to turn sideways to observe visual aids being used. Projecting a student’s computer can be useful in illustrating a common problem that other students might encounter and how to fix them or for allowing students to give a brief presentation from their desks. The link system uses a separate proprietary hardwired network to transmit and switch the video images around the classroom.

This avoids any bandwidth difficulties with using the campus Ethernet. The keyboard and mouse control is implemented using the campus Ethernet.

A Sympodium (Smart Technologies, Inc., Calgary, AB, Canada) interactive pen (smart board) display is installed for the instructor's station. This display allows the instructor to naturally annotate slides or program screens with electronic ink during class, allowing for more possibilities in presenting the material.

Both of these learning spaces are designed specifically for first-year engineering classes and are "owned" by the engineering department. In addition to allowing the customization of the classroom for engineering needs, this ownership helps to build the sense of attachment in both engineering students and in the faculty.

Assessment Methodology:

To begin assessing these learning spaces an instrument was administered to evaluate student engagement and student reaction to the learning spaces. Directly assessing the impact of a learning space on student learning is difficult to impossible. Student engagement has been suggested as an appropriate target for the assessment of learning spaces[12]. The first part of the instrument used in this study is the Student Course Engagement Questionnaire (SCEQ) developed by Handelsman, et. al. (2005).[13] This is a 23-question instrument that asks students about their behavior in the particular class where the survey was administered. The results are grouped to rate four types of engagement: skills engagement, emotional engagement, participation/interaction engagement, and performance engagement. Table 1 shows the questions arranged by these four engagement categories. The numbers before each question indicate the order in which they are asked. Students are asked to respond to these items with the five point Likert scale:

5 = very characteristic of me
4 = characteristic of me
3 = moderately characteristic of me
2 = not really characteristic of me
1 = not at all characteristic of me

Handelsmann, et. al. assigned the four categories based on a factor analysis on the results of a 266 student pilot survey. For examining the engagement possibly engendered by a learning space the Participation/Interaction Engagement is our primary measure. However positive impacts may occur in the other categories as well. Note that this instrument focuses on asking students about their behavior rather than their opinion.

One weakness of this SCEQ instrument for our purposes is that some questions are a better suited to a large lecture style course. For example: *1. Raising my hand in class*, or *9. Taking good notes in class* might not happen in a well engaged project based session because the environment is more open to asking a question with out raising a hand or may be too project oriented to make traditional note taking practical. This might particularly affect the skills engagement measure.

Table 1: The Student Course Engagement Questionnaire (SCEQ) questions organized by engagement factors

To what extent do the following behaviors, thoughts, and feelings describe *you, <u>in this course</u>?*

I. Skills Engagement

4. Doing all the homework problems
5. Coming to class every day
9. Taking good notes in class
10. Looking over class notes between classes to make sure I understand the material
13. Putting forth effort
14. Being organized
17. Staying up on the readings
20. Making sure to study on a regular basis
23. Listening carefully in class

II. Emotional Engagement

7. Thinking about the course between class meetings
8. Finding ways to make the course interesting to me
11. Really desiring to learn the material
21. Finding ways to make the course material relevant to my life
22. Applying course material to my life

III. Participation / Interaction Engagement

2. Participating actively in small group discussions
1. Raising my hand in class
19. Helping fellow students
18. Having fun in class
3. Asking questions when I don't understand the instructor
6. Going to the professor's office hours to review assignments or tests, or to ask questions

IV. Performance Engagement

15. Getting a good grade
16. Doing well on the tests
12. Being confident that I can learn and do well in the class

The second part of the instrument used asks students directly for their reflections on the learning space (Now they are asked for their opinion). The questions for this part of the survey are shown in Table 2. This includes four Likert-scaled items asking students to directly compare their experiences in the classroom of interest to other classrooms. These questions ask directly about interaction with other students and the instructor, time spent on group activities and time focused on a classroom task or problem. Notice these questions directly reflect four of the "Seven Principles for Good Practice in Undergraduate Education." Students are then asked if they use the space outside of class never, sometimes or often. Finally two open-ended questions are included asking the students how the space effected their interactions with other students and the instructor and what they observe is different about the space.

This two-part survey allows examination of both student reported behavior and student opinions about the learning spaces. The survey was administered over the past three semesters to students in the four different first-year engineering courses. There was some over sampling due to students who were in more than one of those classes.

The survey results are supplemented with instructor observations from formal interviews and from informal discussion. The formal interview process is in its beginning and is continuing.

Table 2: Comparison and open-ended questions included in the survey

Compared to classes in rooms other than ET311 and ET315 my					
5 = much more than other rooms 4 = more than other rooms 3 = same as other rooms 2 = less than other rooms 1 = much less than other rooms **Circle the rating that most applies**					
28. Interactions with other students during class were	1	2	3	4	5
29. Interactions with the instructor were	1	2	3	4	5
30. Time spent on group activities was	1	2	3	4	5
31. Time I spent focused on a specific in class tasks or problem was	1	2	3	4	5
32. How often did you use this room outside of class (circle one): often sometimes never 33. How has this classroom space affected your interaction with other students in the class? How has it effected your interaction with the instructor teaching the class? 34. What do you observe is different about taking classes in this room relative to other classrooms?					

Assessment - Student Course Engagement Questionnaire (SCEQ) Results

Table 3 shows the average result for each of the SCEQ factors by course and room. For comparison the results from Handelsman, et. al.[13] are also included. Handelsmans group represented upper and lower division students in psychology, political science and mathematics courses. The current data is strictly for first-year engineering courses. The numbers are consistent across all subgroups with the current data slightly lower in the Skills, Emotional and Performance factors but higher in the target Participation/Interaction factor.

A General Linear Model (GLM) ANOVA analysis was completed using Minatab Statistical Software to evaluate if any of the differences seen where statistically significant. In this approach a regression analysis is used to construct an Analysis of Variance table for an unbalanced design. The model analyzed in this case was a nested or hierarchal design with the ***room*** as the main variable, the ***course*** nested inside of room and ***section*** nested inside of course.

The resulting error estimate used is the pooled variance with in a section. Table 4 shows the resulting ANOVA F statistics and the probability that those F-statistics would arise by random error alone for each of the engagement factors as a response. The table also displays the source degrees of freedom (d.f.) and error degrees of freedom.

Table 3: Average results of Student Course Engagement Questionnaire (SCEQ)

Learning Space	Category/ Course	sample size	Engagement Factor – Mean Scores			
			Skills	Emotional	Participation/ Interaction	Performance
Background Information	Possible Scores		1 - 5	1 - 5	1 - 5	1 - 5
	SCEQ paper	266	3.7	3.5	3.1	4.1
Multimodal Classroom	Intro to Engineering	202	3.5	3.2	3.2	4.0
	Intro. to Engineering Design	89	3.4	3.3	3.5	3.9
	Total	291	3.5	3.2	3.3	4.0
Computer Classroom	Computer Aided Design	119	3.6	3.5	3.3	4.0
	Computer Tools (Matalb)	76	3.6	3.3	3.3	3.9
	Total	195	3.6	3.4	3.3	3.9

A significant effect of the ***room*** on Skills and Emotional engagement is observed in this table. In both of these cases the computer classroom had the higher average score (see Table 3). The course variable had a significant effect on the Skills and Participation/Interaction factors. For the target Participation/Interaction factor the Introduction to Engineering Design had the highest average. This effect could come from this course having the most restrictive prerequisites and there for the most advanced students.

Table 4: General Linear Model ANOVA F statistics and probabilities of null hypothesis for the SCEQ results using a nested model of Section inside of Course inside of Room

	Error d. f.	Room		Course		Section	
Source degrees of freedom (d.f.)		1		2		10	
Engagement Type:		**F**	**P**	**F**	**P**	**F**	**P**
Skills	472	10.6	0.001	4.17	0.016	2.14	0.02
Emotional	472	9.36	0.001	0.49	0.615	0.82	0.611
Participation/Interaction	472	0.01	0.937	4.19	0.016	1.54	0.123
Performance	472	1.03	0.312	1.49	0.227	1.11	0.352

Section had a significant effect on the skills factor. This is a little unexpected as you would hope that the sections of a course would simple be independent random samples. However, in actuality there are often differences in section, particularly due to scheduling. For example a particular section of a course might be convenient to students taking an advanced mathematics class and therefore the skills engagement of that section is higher. In addition, as a commuter campus some of our courses are day classes and some are evening classes which can result in significantly different populations in those sections.

The impact of the academic term was also explored but not found to have a significant effect on the engagement factors. It is therefore not included in the above analysis and its degrees of freedom are allocated to the error estimate.

The critical variable that is not included in this previous analysis is that of instructor. This is likely an important variable however it is heavily confounded with course and may affect the above results for both course and room. The data for this assessment is based on results from courses taught by six different instructors. Five of those instructors taught only one of the courses. The sixth instructor taught all four courses at different times. When the above nested model is analyzed for the single instructor none of the model factors come up as significant at the 95% confidence level, three are close. However, the data for this analysis is more limited.

Assessment – Student Comparison Questions & Room Usage Results

The student comparison and the outside of class room use questions in the second part of the survey were analyzed similarly to the SCEQ. Table 5 shows the mean result by course and semester for these questions. For the comparison questions, 4 was defined as "more than other rooms" and 5 was defined as "much more than other rooms." All means for these comparison questions exceed the neutral value of 3. Time spent on group activities was rated 3.8 or higher across all classes. Almost all averages are above 3.5 for "interactions with other students" and for "time focused on a specific task or activity". It is interesting to note that the highest averages are for Introduction to Engineering Design. This is the last class students take in the first year sequence. This is a favorable response by the students to these modified environments.

For time spent outside of class *never* was coded as a zero, *sometimes* was coded as a one and *often* was coded as a 2. For the Introduction to Engineering class, the average student rating for usage was 1 (sometimes). In all other courses the rating was 1.6 or higher indicating significant use of these facilities outside of class time.

Table 5: Average results of Student Comparisons to other classrooms

Learning Space	Course	sample size	Mean Scores				
			Interactions with other students during class were	Interactions with the instructor were	Time spent on group activities was	Time I spent focused on a specific in class tasks or problem was	How often did you use this room outside of class
	Possible		1 - 5	1 - 5	1 - 5	1 - 5	0 - 2
Multimodal Classroom	Intro to Engineering	202	3.5	3.1	3.8	3.3	1.0
	Intro. to Engr. Design	89	4.1	3.6	4.4	3.8	1.6
	Total	291	3.7	3.3	4.0	3.5	1.2
Computer Classroom	Computer Aided Design	119	3.4	3.3	3.8	3.7	1.6
	Computer Tools (Matalb)	76	3.8	3.4	3.9	3.8	1.7
	Total	195	3.6	3.4	3.8	3.8	1.7

Table 6 shows the result for the same type GLM significance analysis as was used for the SCEQ analysis previously. In this case Academic Term is also included in the model. It is crossed with the previous hierarchy. This new factor is highly significant in all cases where it was not significant for any cases in the SCEQ. The other thing that jumps out is the high significance of the *Course* to almost all questions. This is not surprising and it is important to remember that the learning space simply facilitates the course learning activity design. Courses, instructors and student groups are always the key factors in engagement.

The room had its largest impact on the *Time on Class Tasks*, and *Room use Outside of Class* responses. The former is higher in the Multimodal classroom and the latter is higher in the computer classroom (see Table 5). This latter result is expected as that room is set up as the primary general purpose study room for engineering students and has more computers. Also notice that for the Introduction to Engineering Design class the Multimodal Classroom *Room use* approaches that of the Computer Classroom. This Engineering Design course is project focused and students start using this room for their project work.

Table 6: General Linear Model ANOVA F statistics and probabilities of null hypothesis for the Comparison questions and room use results.

	Error d. f.	Room		Course		Section		Academic Term	
Source degrees of freedom (d.f.)		1		2		10		2	
Comparison Question:		**F**	**P**	**F**	**P**	**F**	**P**	**F**	**P**
Interactions w/ other students	453	0.44	0.507	7.84	0.000	2.58	0.005	5.30	0.005
Interactions w/ Instructors	453	3.41	0.066	1.99	0.138	4.08	0.000	6.60	0.001
Time on Group Activities	454	0.11	0.740	5.60	0.004	1.53	0.126	3.37	0.035
Time on Class Tasks	451	10.47	0.001	5.85	0.003	0.93	0.509	4.75	0.009
Room use outside of class	463	35.79	0.000	25.06	0.000	1.75	0.067	13.69	0.000

The nested nature of this design does lead to some difficulties in interpretation. The impact of Room on *Time on Class Tasks* could be a result of the fact that different classes are taught in each room and the class effect is highly significant. The lowest *Time on Class Tasks* numbers are for the Introduction to Engineering Class. This class has the highest sample size, the lowest number of credits, and is the first class in engineering that students take.

This past fall, a new project was introduced this Introduction to Engineering course. This project involves students designing a system that creates vibrations using LEGO parts and then harvests some of the energy of those vibrations using a piezoelectric chip. This project was designed to encompass more of the course than the previous reverse engineering projects.

Table 7 shows the mean comparison results for a single instructor who taught this course over the previous three semesters. The Fall 08 semester was their first semester teaching this course. It is easy to see an increase in all measures as the instructor teaches for their second semester. With the addition of the new project in the Fall of 2009 you also see clear increases in *Time on Group Activities*, *Time on Class Tasks*, and *Room use* responses. With this new project the Time on Class tasks and room use numbers approach that of the other courses and classroom. This new project is a good example of a key issue with learning spaces – their largest value is in what they make possible and how instructors make use of them.

Table 7: Comparison of Introduction to Engineering results for one instructor by term and with a project change.

Term	Project	Sample Size	Interactions w/ other students	Interactions w/ Instructors	Time on Group Activities	Time on Class Tasks	Room use
F08	Reverse Engr.	72	3.4	2.8	3.5	3.1	0.9
S09	Reverse Engr.	47	3.5	3.2	3.6	3.3	0.9
F09	Energy Harvesting	59	3.6	3.1	4.1	3.6	1.5

Assessment - Qualitative Questions Results

An initial review of all open-ended qualitative questions showed some interesting tendencies. For both spaces students were generally positive or neutral on the impact of the space on interaction. One unexpected result was how often students mentioned that the rooms felt more relaxed than other classrooms and how they liked that fact.

For the multimodal classroom many students mentioned how the trapezoidal tables turning in toward each other encouraged them to interact more with the students near them. Some noted that the cluster arrangement meant that while they interacted well with students at their cluster, they did not interact as much with the rest of the class.

One problem in the multimodal classroom that some students mentioned is the monitors getting in the way of working on non computer activities or impeding sight lines. This is not a serious problem but a redesign of the service core of the clusters could allow a better parking place for the monitors when not in use.

Some noted they felt the room was crowded while a few mentioned that it was roomy. Some of this may stem from the fact that in the Introduction to Engineering course it has sometimes been necessary to put more than the ideal 24 students in the room because of high demand and a historically high withdrawal rate in the first weeks of the term. This is a one-credit course with no prerequisites and sometimes students have signed up for it with out knowing what they are getting into. This pattern of early withdrawal has decreased markedly in the past few semesters and the enrolment practices for this course are changing. Some students also noted being distracted by other students using the computers for non-class purposes.

For the computer classroom students noted that it was easy to interact with the instructor because of the wide isles from the front of the classroom. There were also many comments about the roomy desks and relaxed atmosphere. Some students, particularly from CAD class sections, did note that they got behind when they tried to follow along with the instructor on the main screen while working on their computers that were turned to the side.

A detailed content analysis of the answers to these questions is being completed.

Assessment - Faculty Observation Results

Multimodal Classroom: The response of both students and faculty to this room has been quite positive. Both want their classes in this room. Many students preferentially choose this room over other computer laboratories in the building. Students like the pleasant environment, the widescreen monitors, the ability to move the monitors around, and the ease of working together with a group in this facility. It is often used by student project groups. One group of students regularly met in the classroom for a distance education class – turning an internet class back into a classroom experience.

Before the classroom was up and running there was some concern that the window wall at the back of the classroom might be a distraction. This has not turned out to be a significant issue. This window that opens into a hall makes the room feel more open and inviting. However because the window wall is at the back of the classroom it has not been a big distraction. If anything, the fact that someone could walk by and see what they are doing may deter students from activities such as web surfing that are unrelated to class.

Several instructors have noticed and valued the ease of movement about the learning space. An instructor can get to all cluster groups easily. This has been repeatedly noticed as an asset. In addition instructors can easily get to most individuals in the classroom. The one exception to this is along the side wall away from the door where students are very close to the wall and it is difficult for instructors to access these students individually from behind.

The instructors who developed the new energy harvesting project for the Introduction to Engineering class noted that this project would be impossible with out a space such as this. Students can use a computer based oscilloscope to measure their energy generation, they easily work in teams, and the side counter and storage provide space for project supplies. In addition, it is easy for an instructor to move back and forth between group work and presentation allowing the integration of the project into the class.

The base cluster with three trapezoidal tables is perfect for most classes and activities. However we have found that it is sometimes helpful to add an additional table to a cluster. The purchase of two additional trapezoidal tables is planned. They will be stored in the front corner, under the screen, when not being used to supplement a cluster.

Computer Classroom: One of the first things many people have commented on is that there seems to be more space in the classroom than there was previously, in spite of there being 20% more desks and computers. Combining the one main isle and 10 smaller areas between rows into two large isles has resulted in a more efficient use of space where it is very easy for the instructor to get to any student in the room. It is interesting to note that a drafting classroom in the interior design program was reconfigured in a similar fashion and resulted in a similar gain in space. In addition there is much more direct access a variable height ADA station because it is directly across from the door (see Figure 1).

Moving the system units off the desktops does make student interaction easier. The instructor can easily move to any student in the room quickly and has room to work with a student with out interfering with others work. This characteristic also holds when an instructor or TA visit the classroom between classes to help students working on homework or projects between classes.

However, each student having a computer still tends to discourage interaction; Students seem to be drawn to staying with their machine rather than working with others. Giving out a single worksheet for a group of students and having them fill it out together does help encourage cooperative learning. Also after reconfiguring it was realized that the former classroom arrangement with lots of separate rows did form students into natural groups of two or three. This natural grouping is lost with long rows of six. It may be advisable to put breaks in these rows to create natural groupings of three. For example, the printer table could be moved to the center of the classroom which would be both convent and break the center rows into groups of three.

This reconfiguration does help the instructor to observe how students are keeping up with his instructions or exercises. This configuration, combined with the classroom network, does reduce the tendency of students to use the computers for non-class activities. One student commented that they thought that this was the whole reason we made the change.

This configuration does have some places for improvement. Students along the walls have to turn significantly to see the screen which makes completing "follow the leader" exercises difficult. This is not much of a problem for other exercises and could be resolved with multiple projection screens or monitors. Instructors have also noted that a way to cut across the center rows in the back of the classroom would make it quicker to reach students on the opposite side of the classroom.

Conclusions

Cooperative and active learning approaches can be incorporated in to a class in any setting. Course design, instructor and the students involved are clearly the predominate factors. However a learning space and associated instructional technology can facilitate a more active environment. It can provide the instructor easy access to students, a relaxed environment that raises expectation of interaction, easy student-to-student interaction.

When a new space is developed the use of the space and instructional design are key to seeing the potential of the space utilized. A new project in an Introduction to Engineering Design course increased active use of learning space both in class and outside of class.

Students rated both the Multimodal Classroom and the Workshop Computer Classroom as more interactive than other spaces where they had class. The two classrooms showed fairly similar results with several hints in the data pointing to the importance of the instructor and the specific course. Both classrooms showed somewhat higher Participation/Interaction engagement than a reference case. However this reference is for a quite different population of students and type of classes and may not be a valid comparison. The workshop arrangement was found to increase the classroom capacity by 20%.

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