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Promoting engagement in active-learning classroom design

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While the interior design of classroom spaces has evolved to support active learning methods, few studies have isolated environment changes from curriculum changes to understand the impact of space on behavior (Brooks, Walker, & Baepler, 2014). Adapting an observation instrument from the Brooks (2012) study, "Space and Consequences", this research extends previous work in a unique circumstance that allowed the observation of a course which alternated class meetings between two differently designed spaces. We gathered perspectives from 296 students and 9 instructors along with classroom observations which highlighted eye contact as important to both instructors and students in promoting engagement.

Introduction

Throughout history, learning spaces have evolved with education delivery and purpose (Park & Choi, 2014). Transformation of space and curriculum delivery for active learning has occurred simultaneously. This concomitant change operates under a set of assumptions that the physical environment influences experience, behavior, and attitude. Few studies, however, have isolated environment changes from curriculum changes to understand the influence of space on behavior (Brooks, 2012; Brooks et al., 2014).

As active learning procedures for curriculum delivery have become more prevalent, so too has the exploration of classroom space arrangement and design. Experimental classroom arrangements, beginning with the North Carolina State University Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project in the 1990s and the Technology Enabled Active Learning (TEAL) project at MIT, led to additional projects such as the Transform, Interact, Learn, Engage (TILE) classroom experiment at the University of Iowa (Brooks et al., 2014; Soderdahl, 2011; Van Horne, Murniati, Gaffney, & Jesse, 2012) and the development of Active Learning Classrooms (ALCs) at the University of Minnesota (Brooks et al., 2014). These projects sought to adjust physical learning spaces to support the integration of new technology and pedagogical approaches that are student-centered rather than teacher-centered.

These, and other projects, support active learning methods and room arrangements as effective strategies for curriculum delivery evidenced by improved student learning outcomes (Whiteside, 2014). Results from the SCALE-UP and TEAL classroom projects indicated that the newly designed classroom and curriculum contributed to reduced failure rates and increased conceptual understanding of material (Belcher & Dori, 2005; Brooks, 2012). Yet, Larsy, Charles, and Whittaker (2014) showed that students achieved greater gains using student-centered pedagogies, promoting active construction of knowledge over teacher-centered lectures, regardless of the classroom design. Conversely, their study also showed that the use of teacher-centered pedagogies in student-centered, or "sociotechnological" (arrangements that emphasize student collaboration and technology integration), environments produced the lowest gains (p. 010116-1). Whether or not a teacher's pedagogical approach aligns with the room arrangement appears to affect student outcomes.

Multiple publications advocate the change of classroom environments to promote active learning strategies with embedded use of technology. EDUCAUSE (a prominent association for the integration of IT and higher education) has led the conversation (Brooks, 2012; Oblinger, 2006) along with a journal dedicated to the topic, the *Journal of Learning Spaces*, issuing its first volume in 2011. Steelcase continues to advocate for the transformation of classroom space to promote active learning with multiple case studies and articles on the subject (Steelcase, n.d.) including a recently funded literature review on the effects of active learning spaces on student engagement and outcomes (Steelcase,

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2019). A 2014 special edition of the journal *New Directions in Teaching and Learning* dedicated ten chapter-articles to active learning spaces that covered topics ranging from history of active learning spaces, and assessment strategies, to physical environment considerations. The conclusion of this special issue called for the replication of various quasi-experimental research designs to add to the body of knowledge (Whiteside, 2014).

Brooks (2012) conducted one such quasi-experimental study of active learning classrooms at the University of Minnesota. The purpose was to investigate the impact of space and behavior by observing students and a teacher in two different classroom settings. The physical environment in this study became a variable with one traditional, teacher-centered, arrangement and one, student-centered, active learning style arrangement. The traditional, teacher-centered, classroom was arranged with rows of tables and chairs facing an instructor podium and projection screen along one wall. The student-centered active learning classroom (ALC) was arranged with large round tables, projection screens on multiple walls, and a teacher podium in the center of the space. Each space had a capacity of approximately forty-five students. The teacher did not make concurrent pedagogical changes, delivering the same curriculum in two different classroom settings making this study one of the first to investigate classroom adjustments without making simultaneous pedagogical changes. Two different class sections of students met at the same time of day on different days of the week in the two different rooms.

Using a time interval observation instrument, observers recorded classroom activities, student engagement with task expectations, and environmental conditions. Factors that contribute to comfort such as access to natural light, quality acoustics, lighting, and temperature, were recorded to ensure there were not major differences between the room conditions. These factors have been shown to contribute to successful learning environments (Scott-Webber, Marini, & Abraham, 2000). On task behavior was determined by outward student attention such as facing media, content, or the instructor, as well as taking notes and engaging in discussions. Off task behavior was indicated if students engaged in side-conversations or paid attention to personal media devices during periods when not expected to do so. It was noted that the measures for on and off task behaviors may not have been accurate if students were discussing content one-on-one or searching for additional information with their personal devices. The observation instrument was later updated to record the types of behaviors (forward facing, on personal media device, or taking notes) students were engaged in at any given time rather than generally indicating on or off task.

Results from the Brooks study indicated that the teacher spent more time lecturing in the traditional classroom and more time in discussion in the ALC. This study illustrated that the ALC arrangement is conducive for active learning approaches while the traditional classroom arrangement is conducive to lecture approaches, suggesting that instructors should adjust their pedagogy to correspond with the type of space that they are assigned.

Adapting the research instrument used in Brooks (2012) and building upon its findings, the purpose of this study was to analyze instructor-to-student engagement and peer-to-peer engagement in a teacher-centered, tiered classroom and in a student-centered design studio classroom. Due to special circumstances outlined in the background, researchers in this study had the opportunity to observe the same groups of students with the same teacher in two different classroom environments, one teacher-centered and the other student-centered. This ability to observe the same actors in two different environments is a departure from Brooks that may provide insight into what aspects of the classroom environment impact student engagement. Also differing from Brooks was the fact that the researchers used a mixed-methods approach conducting focus groups with instructors and quantitatively surveying students. Research results led to the development of design suggestions to support student engagement.

After a pilot study using the updated observation instrument from the Brooks investigation, researchers revised the tool to better align with activities taking place in this context. These changes included recording teamwork, individual work, and frequency of eye contact. Eye contact was recorded by estimating the percentage of students who gazed in a direction appropriate to the activity such as viewing the teacher or projected media presentations during lectures, students glancing at each other during discussion or teamwork activities, or looking at their computers during individual work time. Advances in social neuroscience, specifically areas that center on how the brain interprets social situations, or the "social brain", demonstrate how humans interpret eye contact to read social situations, including the social attention of others (McDonald, 2009). Eye contact, especially during teamwork situations, was added to provide insight into social attention between teammates and between students and teachers. This is important as an underlying assumption to active approaches that interaction between students fosters motivation and supports stimulating growth (Schaber, Wilcox, Whiteside, Marsh, & Brooks, 2010).

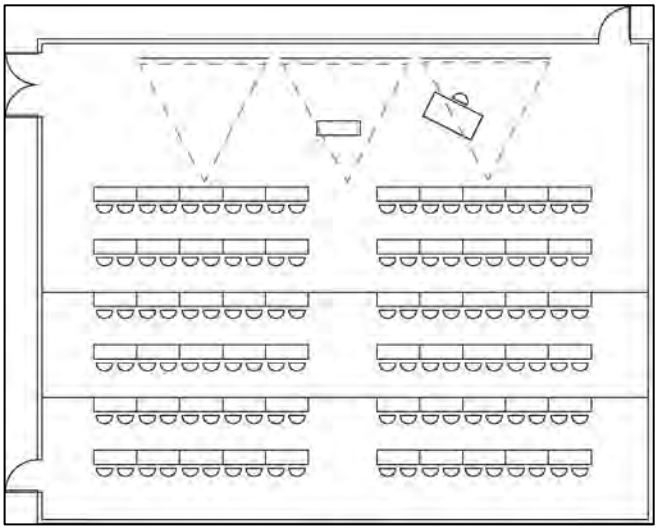

Figure 1.

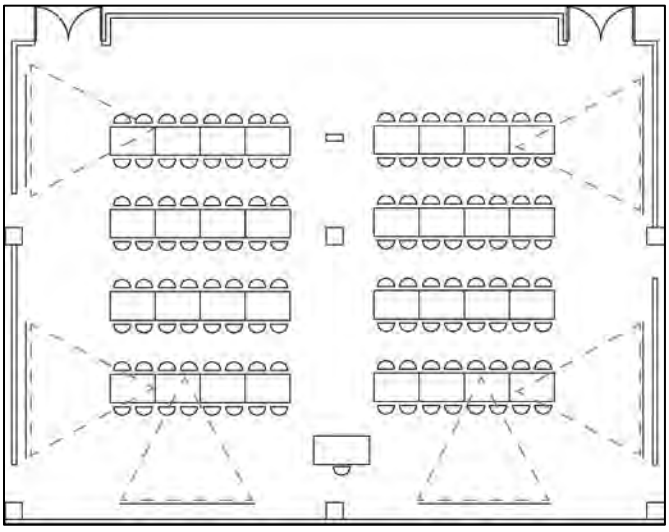

Figure 2.

Background

The call for active learning is not new. In 1992, the National Science Foundation (NSF) report *America's Academic Future* concluded that standard lecture-based delivery of science, engineering, and mathematics education should be diminished in favor of inquiry-based learning. This was echoed in the 2010 NSF report advocating the disestablishment of lecture instruction. The context of the study presented in this paper centers on one university that responded by simultaneously redesigning its introductory engineering curriculum while developing a new physical space for delivery of the course (Reed-Rhoads et al., 2010). The curriculum was revised to promote "inquiry-based learning through networked, technology-based instruction" (Reed-Rhoads et al., 2010, p. 1) in a flipped-classroom or active learning format, integrating hands-on, project based, in class assignments. The intent was to provide hands-on experiences which served to motivate learning (Reed-Rhoads et al., 2010).

Two spaces were designed for the delivery of the curriculum. One of the classrooms, a *tiered classroom* (see Figure 1), was designed as a university-wide teaching space and had limited design input from the introductory engineering teaching team. This space was designed as a mix of instructor-centered activities (e.g., lecturing, facilitating discussion) and occasional student-centered, active-learning activities (e.g., project work, team work). The tiered classroom is three tiered, with each tier containing two large, fixed tables. Detached mobile chairs are utilized at tables to allow student mobility. This gives students seated at the front tables the flexibility to turn around and share the back table (on each tier) for group work. Typical of many standard lecture classrooms, teaching media and a lectern are present at the front of this classroom. The other classroom, the *design studio* (see Figure 2), was designed primarily by the introductory engineering teaching team and was intended to be used more for student-centered activities while still allowing for instructor-centered facilitation. The design studio has multiple rows of cafe-height tables and mobile swivel task chairs; it is not tiered. Students sit on both sides of the tables. Teaching and projection media are present in six locations, along three walls, with a central teaching station. The front, or entrance wall, is made of glass for high visibility (Reed-Rhoads et al., 2010). Each projection area is capable of displaying various material. The large space can be divided in half by a mobile wall. Project and media storage areas can be accessed through openings on each side of the room.

Since its inception, the curriculum and class structure have continued to evolve. The original intent was to deliver tailored portions of the curriculum in the specific rooms, however as enrollment grew and more time was devoted to project-based teamwork, it became difficult to schedule the rooms around content delivery. To allow all students access to the design studio, the first-year engineering class alternates each scheduled class meeting between the tiered classroom and design studio, regardless of planned activities.

The fall semester course, Transitioning Ideas to Innovation I, is a first-year course designed to introduce data analytics, modeling, engineering design, and engineering disciplines to all engineering majors. The course allows students to "practice making evidence-based engineering decisions on diverse teams, guided by professional habits. In addition, [students] develop solutions to engineering design and modeling challenges and explore engineering careers"

delivered in a flipped classroom approach (University Syllabus, 2019). Before class, students are to watch "custom developed online modules (videos) related to course topics" and then apply the knowledge in class working on different activities primarily in teams of two to four (University Syllabus, 2019). The course is designed for students to work consistently with the same teammates (Reed-Rhoads et al., 2010).

This course serves an enrollment of 120 first year engineering students per section. Due to the size of the freshman engineering program (16 sections taught by 14 different instructors), there are several control measures put in place for the curriculum, therefore instructors are not allowed to modify the content. Classes switch back and forth between rooms for each class meeting held twice per week. The curriculum does not change, regardless of the scheduled meeting room. The same activities, including lecture, discussion, team work, and individual work, are taught in both rooms. The consistency of curriculum delivery, similar to Brooks (2012), controls activities taking place during observations.

Active Learning and Engagement in STEM Education

Support for active learning is ubiquitous. It has developed in response to advances in neuroscience, changing social dynamics, as well as consideration for social, emotional, and physical contexts of learning (Committee, 2018; Walczac & Wylen, 2013). Active learning operates with the assertion that it affords immediate application and concept acquisition, fostering long-term retention. It is believed that using learner-centered, actively engaged methods will provide a more effective foundation of skills necessary for professional success than the traditional lecture approach (Mason, Shuman, & Cook, 2013).

There are, however, varieties of methods and modes of instruction that constitute active learning, rendering a need for flexible space design. In 1998, Steelcase proposed a quadrant gradient of activity zones from formal and individual work to informal and group interaction (Scott-Webber et al., 2000) recognizing this issue. This quadrant is still used in the design and promotion of classroom furnishings. Although there are many techniques for the delivery of active learning, engagement is integral to the learning process. Classroom engagement is widely accepted as an indicator that influences learning outcomes and is positively linked to critical thinking and grades (Carini, Kuh, & Klein, 2006). To support current pedagogical approaches, it is important that parties responsible for the design and construction of classroom spaces understand how engagement is defined, measured, and promoted.

The curriculum structures most frequently discussed in engineering education are active, collaborative, cooperative, and problem-based learning (Prince, 2004). Prince (2004) defined each type of activity with nuanced differences. While homework could be considered active engagement, active learning promotes the incorporation of activities in the classroom in contrast to the passive lecture format. Collaborative learning encompasses any group-based activity. Cooperative learning is a group approach where students are assessed individually. The approach seeks to promote "cooperative incentives rather than competition to promote learning" (Prince, 2004, p. 223). Problem-based learning (PBL) introduces activities in which students work on real-world problems to provide context and motivation in learning material. PBL could be collaborative, cooperative, or individual but is typically learner-led with the instructor acting as a facilitator (Kelly et al., 2005). Problem-based learning is commonly paired with the flipped, or inverted, classroom approach (Mason et al., 2013). The flipped classroom may include traditional reading but also employs technology for pre-exercises, viewing lectures, videos, tutorials or presentations prior to class meetings. This allows time for the material to be discussed and applied during class sessions (Mason et al., 2013).

A study by Kelly et al. (2005) concluded that standard lecture, problem-based learning, and team-based classroom delivery promoted different types and levels of student engagement. In this case, engagement was defined as in-class learner-to-learner and learner-to-instructor interaction. In the lecture-based classroom, students were primarily engaged with the instructor or in self-engaged activities such as reading or writing. The PBL classroom primarily promoted learner-to-learner engagement with few recorded instances of instructor or self-engaged activities. Team-based learning was similar to PBL classrooms but with much higher student-to-instructor ratios (up to 200:1) and employed out-of-class, or flipped-classroom, instructional assignments, and in-class problem-based teamwork. Team-based class approaches promoted high levels of learner-to-learner engagement but with increased instructor- and self-engaged activities. Team-based structures seemed to enhance interactivity and controlled content delivery blending the benefits of PBL and lecture structures.

Learner Engagement and Physical Space

The space in which teaching activities take place can either support or hinder their success. A fixed classroom arrangement can make the blending of different types of learning modes difficult. McDavid, Carleton Parker, Burgess, and Robertshaw (2018) suggested that space affects teaching and engagement based on the teacher's perceived

self-efficacy for a desired curriculum structure. Classroom preferences, for teachers and students, are dependent upon the type of activities or content delivery mode (Walczak & Van Wylen, 2013). Whatever the type of content delivery, if the teacher's epistemic beliefs match the classroom layout, teaching and learning will be more successful. The delivery of teacher-centered pedagogies in student-centered classrooms, and vice versa, are ineffective producing lower gains in student learning outcomes (Larsey et al., 2014).

Given the variety of active learning modes, classroom layouts need to support a variety of teaching and learning tools. Physical space has the potential to limit content delivery and communication as well as affect attitudes and perceptions. The arrangement of physical space conveys educational philosophy and shapes attitude (Tom, Voss, & Scheetz, 2008), or as Monahan (2002, p. 5) calls "built pedagogy". Fixed furnishings in a high-density arrangement restrict movement and flow, while open, small scale, movable equipment suggests that space can be adapted for perceived needs. The spectrum in arrangement of fixed versus flexible, or fluid, spaces are imbued with meaning, offering perceptions of discipline or of freedom and exploration (Monahan, 2002). The communicative effects of the classroom arrangement, or behavior setting, convey expectations to students and teachers for the types of activities that will take place.

Students perceive university investments in the creation of fluid spaces as a reflection of concern for quality of education and personal attention. Students feel privileged to learn in these spaces and they feel responsible for their ability to pay attention during class (Tom et al., 2008). Attitudes toward traditional and active learning settings show that students, in both the United States and international settings, identified the active learning environment as more inspirational and exciting (Park & Choi, 2014; Tom et al., 2008). It is cautioned, however, that these effects may be due to the novelty of the new, visually pleasing space (Tom et al., 2008). As Thomas (2010, p. 502-503) states "Physical, brick-and-mortar learning spaces have a lifespan that easily outlasts the definitions and learning theories of which they are an embodiment." They warn that as novelty wears off and pedagogy changes, perception of space along with its effectiveness may also change. A study of active learning spaces in Singapore, however, suggested that novelty, alone, may not a be a major factor for engagement, rather space utilization, class activities, and "fit" are stronger indicators of perceived engagement and learning (Lim Sok Mui, Augustin Cea Caprio, & Ming Ong, 2019).

The study presented in this paper compared two different types of classroom arrangements that were designed to accommodate active-learning activities. The space utilization and "fit" between the two layouts is similar, but the messaging is different. The tiered classroom embodies a centralized, teacher-oriented, signification, while the design studio represents a decentralized, student-oriented, approach. The comparison of two environments that afford active-learning, group activities is unique to this study.

Method of Inquiry

The researchers used a mixed-method of inquiry to analyze engagement in two different classrooms. Qualitative and quantitative data were collected in 1) focus group listening sessions with faculty, 2) classroom observations with a modified instrument adapted from Brooks (2012), and 3) a student survey. To facilitate deeper understanding, the study design was triangulated through multiple sources (instructors, teaching assistants, students) as well as research methodologies. Finally, findings were synthesized into design recommendations that support engagement and were applied to a prototypical classroom design conducive to exploring their practical application.

The course is taught in two differently designed classrooms and meets twice per week for 110 minutes both times; once in the design studio classroom (student-centered) and once in the tiered classroom (teacher-centered). Because there are 16 sections of the course, half of the sections start the week in the studio classroom and half begin in the tiered classroom, then they switch for the second meeting of the week. Each of the classrooms accommodates a section size of 120 undergraduate students, 4 undergraduate teaching assistants (TA), 1 graduate teaching assistant (GTA), and 1 instructor.

Data collection

Focus Groups

Researchers conducted two focus group sessions with nine instructors of the course. Both sessions occurred in a small meeting room situated between the tiered classroom and the design studio, but not directly connected to either. The first focus group included two researchers and four participants. The session lasted 62 minutes. Participants' experience teaching the course in these classrooms ranged from one to eight years with a mean of three years of experience. The second group comprised one researcher and five participants. This session lasted 58 minutes. Participants' experience teaching the course in these classrooms also ranged from one to eight years with a mean of 4.8 years. Two of the participants in this group noted that they also had experience teaching in a SCALE-UP classroom at another university.

The focus group script was developed through guidelines provided in the texts *Focus Groups: A Practical Guide for Applied Research* (Krueger, 2014) and *Focus Group*

Methodology: Principle and Practice (Liamputtong, 2011). Questions centered on perspectives regarding the functions, layouts, and activities in each classroom and included:

- *What is it like to teach in the Design studio?*
- *What is it like to teach in the Tiered classroom?*
- *What words would you use to describe the atmosphere?*
- *What is the most defining feature of each space?*
- *What are the challenges of teaching the same course and section in two different classrooms?*
- *How is TA interaction different between the two rooms?*

Observations

The timed interval observation instrument used in Brooks (2012) was implemented with context specific modifications based on class structure and preliminary data collected from faculty focus groups as well as a piloting of the observation protocol. Two researchers conducted the observations and met regularly, checking consistency in the use of the instrument. Two sections taught by different instructors were observed over four class periods, viewing a consistent curriculum delivery in each room. For example, class meeting #21 was observed in both the studio classroom (taught by Instructor A) and the tiered classroom (taught by Instructor B). For their next class meeting, students and teachers switched rooms. Activities and engagement measures were recorded at 2-minute intervals for the full 110 minutes of the meeting. Activities, recorded on a predetermined table, included lecture, announcements (an unplanned full class interruption), discussion (an interactive full class conversation), team work, individual work, instructor monitoring (walking or peering around the classroom during team or individual activities), and consultations (one-on-one between the instructor and TA, TAs consulting with students, instructor consulting with students). Degree of student eye contact with the instructor or presentation screen observed during lecture, announcements, and discussion was assessed at each two-minute interval as a potential measure of engagement. Activities were marked as an instance if they occurred during the two-minute interval. Eye contact with the instructor or presentation screen for each instance was assessed on a scale from one, little to none, to five, meaning most or all of the students were making eye contact.

Location of the teacher was tracked using a behavior mapping approach at each of the two-minute intervals. Notations were made to indicate position relative to the interval and whether the instructor was stationary or moving at the time of marking their position. Guest presenters were regularly invited into the classroom environment. Guests were tracked as teachers and noted with a "G" designation when present. Maps were translated into gray scale coded diagrams with light dots indicating moving position and darker dots indicating stationary status. Dots were connected with lines in order of position relative to the intervals. Lines connecting dots at the beginning of class were light in color and progressively darkened later in the class period. The light to dark gradation provided visual differentiation allowing researchers to study movement and location patterns. Although lines do not represent a path of travel, these helped visualize where instructors occupied the space and how often they moved.

Questionnaire

Every semester first year engineering students are given the opportunity to complete an end of the semester questionnaire for five extra credit points, approximately .5% of their final course grade. The online questionnaire typically includes several types of queries including demographics (gender, citizenship) and course feedback. Because this group of students is frequently targeted for research initiatives, outside investigators are allowed an opportunity to add questions to the survey. Additional question sets are randomly assigned to a portion of the participants. For this investigation, seven questions were added to the survey related to the two classroom environments. The questions included six statements of agreement utilizing a 5-point Likert framework (1 *strongly disagree* to 5 *strongly agree*) and one open-ended question. Questions can be found in Table 3 and results are detailed in the findings.

Findings

Findings from focus groups, observations, and the student survey indicated distinctions in the perception of student-to-student and student-to-instructor engagement for each classroom type. Taken together, these highlight social cues in the behavior setting, visibility, and orientation as indicators of the perceived ability to engage in class activities.

Focus Group

Results from focus groups highlighted the instructors' perception of teacher-to-student engagement as well as perceived student engagement with course activities in each classroom. Three major categories of responses related to engagement emerged when discussing their experiences teaching in each room: eye contact, movement through the space, and the behavior setting (see Appendix for Table 1). Teachers indicated a preference for lecture-based activities in the Tiered classroom referencing eye contact, or sightlines, as an indicator of engagement as well as the spatial layout communicating a behavior setting appropriate to guided learning. They indicated it was easier to move around the Design studio, which fostered more distributed interaction

with students. Movement in the Tiered classroom was more targeted in response to specific questions. Finally, teachers noted that the TAs and peer teachers tend to be more engaged in the Design studio through informal conversations, speculating that tall tables and chairs aided communication. Tall tables and chairs not only minimized power dynamics in seated versus standing body positions, but also communicated a different type of behavior setting that is more informal than the forward-facing desk seating found in the Tiered classroom. One teacher noted that the way they respond to students in each room is different, which reflects informal interactions in the Design studio and more formal interactions in the Tiered classroom, communicated by each behavior setting.

Observations

Observation data (see Table 2) indicated distinctions between the two classrooms. As Table 2 indicates there were differences notably related to the amount of time of lecturing, announcements to the class, discussion, consulting with students, and monitoring.

Instructors in the Tiered classroom spent an average of 3.0 additional minutes lecturing to the entire class. Correspondingly, in the Design studio, they spent an average of 5.25 further minutes making whole class announcements during work time per class period. Additionally, the Tiered classroom following a Mann-Whitney non-parametric comparison of means had a significantly higher value for student eye contact (3.66 vs. 2.41, $p < .05$) during teacher led instructional activities (lecture, discussions, and announcements). This may indicate that the Tiered classroom is more conducive to maintaining attention and focus during the lecture, which lasts longer and requires fewer interruptions for announcements to keep the class on track. Instructors in the Design studio spent an average of 2.25 more minutes on class discussions, suggesting that the Design studio is more conducive to this activity. In both cases, observations supported the formal and informal behavior settings indicated in faculty focus groups.

There was also a difference in the nature of providing students with consultation in the two classrooms in which TAs spent more time consulting with students (3.50 more minutes per class) in the Design studio which was reiterated in the focus group listening sessions. However, observations indicated that the instructor spent less time consulting with students (2.75 fewer minutes per class) in the Design studio. Juxtaposed with focus group responses, this may indicate students receive more directed feedback, as needed, in the Tiered classroom (responding to raised hands) rather than monitoring, or checking in, in the Design studio classroom.

Table 2. **Observation Results using an Instrument Adapted from Brooks (2012) Study "Space and Consequences"**

Observation	Design Studio (min)	Tiered Classroom (min)	Difference (min)
Lecture	14.25	17.25	-3.00
Class discussion	4.5	2.25	2.25
Announcement to whole class	11.25	6	5.25
Consulting with TAs	17.5	18.75	-1.25
Consulting with students	19.5	22.25	-2.75
Monitoring	17	14.5	2.50
TAs consulting with students	21.25	17.75	3.50
Team work	30.25	30.75	-0.50

Note: Observation data recorded in average minutes over course of 8 hours of observation for each classroom.

Behavioral maps captured the average number of instances for the teacher in motion and the teacher in a stationary position in the Tiered classroom were roughly the same. In contrast, the Design studio recorded teachers moving approximately one-third more often, on average, than in a stationary position. This tendency to move around appears to support the observation that the teachers spend less time in consultation with students in the Design studio. It is possible that the increase in consultation engagement with TAs could account for the decreased consultation time with the teacher. Further study should be done to understand these trends.

In both classroom types, the documented teacher location tended to be either at the front of the room or in the aisle between the long rows of student desks. Although the Design studio was not designed to have a front, a teacher presentation station was located at one end of the middle aisle. Figures 3 and 4 are examples of the behavioral maps, illustrating the same teacher in two different environments. The highest concentration of time spent in the middle aisle tended to be near the presentation station in the Design Classroom. Even without a designated front to the classroom, teachers used the presentation station as a home base in order to start class, conduct lectures, facilitate discussions, and make announcements, similar to classrooms with a designated front.

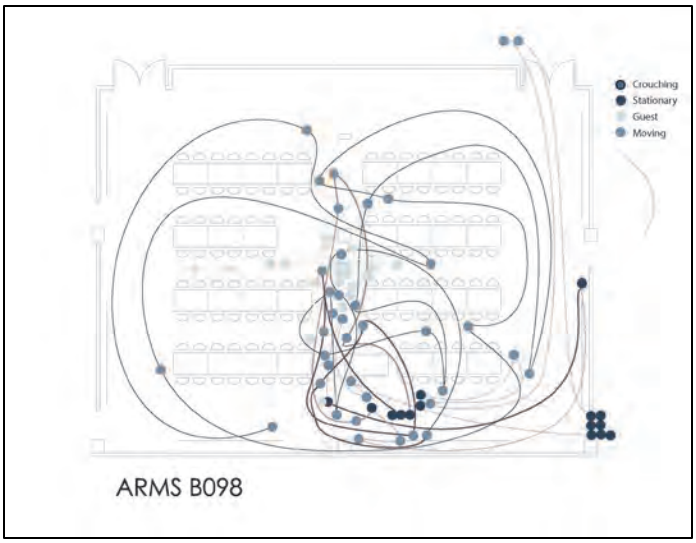

Figure 3.

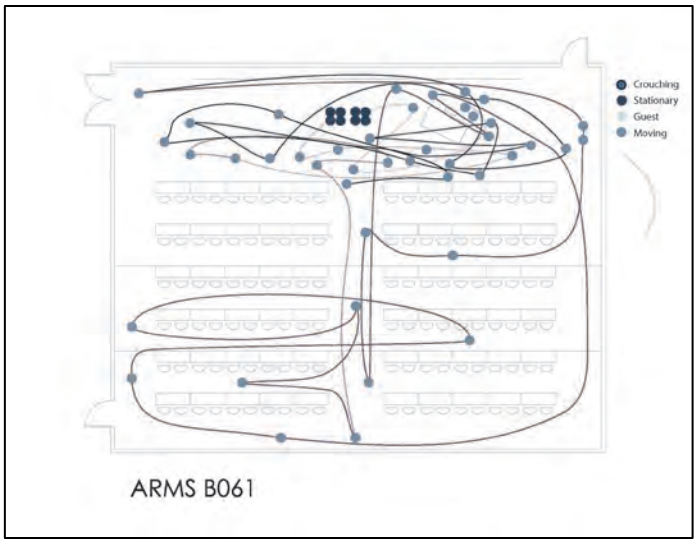

Figure 4.

Questionnaire

The end of semester course questionnaire is an extra credit option offered to all students enrolled in the course (n = 1,824). Of the students who chose to participate (n = 1,651), 296 were randomly assigned the seven-question set for this study. One hundred percent of the participants assigned the question set (n = 296) completed the questions. They were asked how much they agreed with the statements listed in Table 3 for each classroom and responded on a five-point Likert scale (1-strongly disagree to 5-strongly agree).

As Table 3 indicates, student respondents showed statistically significant differences between the Design studio and Tiered classroom. Responses indicated engagement with peers and interacting with other teams is easier in the Design studio. While not statistically significant, the Design studio also showed higher scores for general participation and ease of interacting with the TAs and graduate teaching assistant (GTA). The Tiered classroom did show a slight advantage in students feeling engaged with the instructor. Although not statistically significant, these higher scores were also reflected in observations, depicting students spending less time in consultation with teachers but more time with TAs in the Design studio classroom in contrast to the Tiered classroom.

The open-ended question (n = 264), *"What changes to the ENGR 131 classrooms and physical spaces would improve…"* yielded a variety of responses that were reviewed by the researchers. Some commentary drew attention to perceived, yet distinct, strengths of each room including peer-to-peer engagement in the Design studio and learner-to-teacher engagement in the Tiered classroom. Student comments regarding visibility and orientation appeared to explain these differences. Table 4 (appendix) includes a sample of responses from different students.

Table 3. **Student End-of-Semester Survey Results**

Question	*Design Studio*	*Tiered Classroom*	*Difference*
I felt engaged with my instructor	3.65	3.74	-0.09
I felt engaged with my peers	4.14	3.91	0.23**
I felt encouraged to participate	3.78	3.65	0.13*
It was easy to interact with other teams	3.86	3.39	0.47**
It was easy to interact with the PT (Peer Teachers) and GTA (Graduate Teaching Assistants)	3.93	3.66	0.27**
I enjoyed attending class in this room.	3.86	3.83	0.03

Notes: Engineering student (N=296) classroom survey means and matched-pair, two-tailed T-test results comparing the two classrooms. * indicates significance at p<0.05 and ** indicates significance at p<.001.

Student survey responses punctuated the importance of sight lines as critical to maintaining engagement with teachers and peers. Responses demonstrated that visibility, through sight lines, is the main metric students consider for engagement whether peer-to-peer or learner-to-teacher. Both types of engagement appear to be desired depending on the type of activity occurring at any given time in the course of a class meeting.

Implications

This study sought to understand if there are distinctions in engagement due to different classroom layouts. Student-to-student and student-to-instructor interactions are both important considerations in classroom engagement (Kelly et al., 2005). Open-ended student responses supported the interest in both types of interactions in the classroom. Focus groups, surveys, and observations confirmed that because each classroom was designed for different activities, perceptions of engagement changed accordingly. In a push to implement team based, active learning environments that promote engagement, caution should be employed not to disregard the role of the instructor, not just as facilitator, but also as content expert and mentor. A possible way to bridge teacher-centered and student-centered spaces could be to focus on team-based learning that promotes aspects of both student-to-student communication as well as instructor content delivery (Kelly et al., 2005). Our findings indicated that students and teachers prefer clear sight lines that afford eye contact between students and teachers and promote informal conversation as well as targeted assistance.

Although context specific, our conclusions confirm that lecture style classrooms are conducive for lectures and group work and studio style classrooms are perceived as better for group work (Larsey et al., 2014; Lim Sok Mui et al., 2019; McDavid et al., 2018; Walczak & Van Wylen, 2013). What this study also illustrated, however, is that in reality, instructors pull from a wide range of teaching techniques in a single class period, as well as across the curriculum. A one size fits all approach to classroom design will not work if we do not consider the multiple modes of communication required for delivery to a diverse student population. A classroom should afford lectures when lectures are appropriate, individual concentration when required, and group work when it is befitting. A guide on the side is not adequate if students are not able to access them when needed. This challenges assumptions about classroom design as responsive to dichotomous, lecture versus active, teaching models instead affording a balance of guided and self-constructed learning. While some recent design responses introduce classroom furnishings that embody total flexibility through mobility, they manifest within environments that may appear chaotic and in disarray. An environment in disarray can lead to stress, anxiety, and psychological discomfort (Scott-Webber et al., 2000). Other layouts prioritize sight lines to content and technology, diminishing the importance of social interaction. In an effort to move away from teacher- centered pedagogy and space arrangement, these tend to be more technology-centered than learner-centered.

The Tiered classroom in this study came close to striking a balance between group work and individual focus. Although students spent a similar amount of time engaged in teamwork in both classroom environments, they perceived this room was not as effective for engaging in group collaboration as the Design studio. Because both rooms accommodated group work, the difference in perception may be due to expectations of the behavior setting. Focus groups, observations, and the student survey indicated that students spent less time communicating with TAs in the Tiered classroom but showed possible favor for instructor engagement. The Design studio classroom was perceived by students as promoting team structures and informal engagement with TA's. Yet, teacher focus groups and open-ended student survey responses indicated the Design studio was not received as well for formal interactions such as lecture, presentations, and instructor engagement.

Student surveys communicated a perceived importance of sight lines as critical to motivation and engagement with peers and teachers. Focus groups with teachers also highlighted eye contact as a perceived measure of student engagement with lectures, which was reflected in observations. Taken together, we identified sight lines as a key factor in the social environment. If we aim to promote active and social construction of knowledge, fulfilling basic modes of social communication are necessary. As McDonald (2009, p. 138) points out "eye contact engages the whole person and implicitly communicates attention and valuation in a unique way." Eye contact can help build trust between teams and instructors and capture attention which is beneficial to a positive learning environment.

Prototypical Classroom Design

Based on these findings, specifically slight lines as a factor for engagement, a prototypical classroom design was developed to explore this recommendation in a practical application (see Figure 5). The classroom designed was offered to the Engineering Education faculty for consideration in planning future facilities.

Design for Peer-to-Peer Engagement

Students face each other at tables in groups of four (the desired group size for the course), similar to the original Design studio. Open-ended survey responses indicated that students found this arrangement to be preferred when working in teams. Two table groups are placed together allowing circulation access around each team for ease of mobility. This ensures that no groups are constrained in a middle position, making it easier to move in close proximity to teammates on the opposite side of the table as needed. During observations, students at the end of long rows were observed moving around tables to work with teammates on

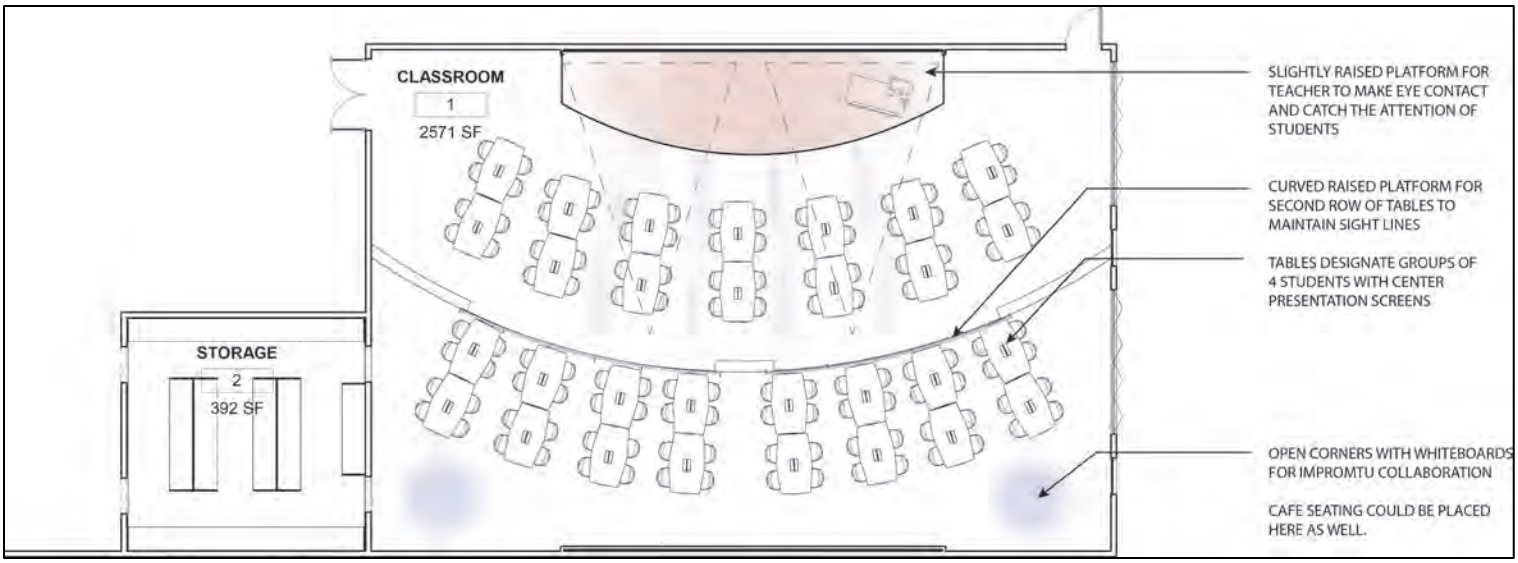

Figure 5.

the other side, while students in the middle tended to turn their laptops.

Employing a technology rich environment is important to many methods of active learning curriculum designs. Students in the Design studio were observed cradling laptops in their forearms and rotating to show their screens to peers across the table. This may be partly due to long rows of tables with multiple teams confined in center positions. Screen share can be made easier by plug and play monitors at each group of four. Furniture systems exist which allow screen share within peer groups as well as by the teacher. Many of these, however, employ large monitor screens at the end of tables which block sight lines that student questionnaire responses indicated were important in maintaining peer-to-peer and student-to-instructor engagement. Therefore, this prototype suggests smaller, conference style, screen tents in the center of each group. This allows students the ability to continue to face their peers while looking at screen content.

Design for Learner-to-Instructor Engagement

A designated front of the room, or teaching area, allows clear sight lines for formal instruction. One tier elevates a portion of the class for easy viewing of teaching area. Tables are arranged perpendicular to the presentation wall, mitigating the problem of students facing opposite the teacher during formal instruction (see Figure 6); a slight curve enhances sight lines. Incorporating a raised floor with easy electrical access can allow furniture arrangements to be modified as appropriate, promoting flexibility in future configurations.

Following focus group findings regarding eye contact, movement, and behavior settings, tall tables in sets of two are recommended in this prototype classroom. This configuration allows instructors to easily approach and communicate with students, promoting informal student-teacher interaction by mitigating power dynamics of seated to standing body position and a behavior setting that communicates informal interaction. With short rows of two teams, ample circulation is present for instructors to monitor progress and to access groups when needed. Multiple aisles connecting directly to the teaching area, where teachers tended to hover in both observed classroom settings, allow easy access to student groups.

For accessibility, standard height tables should be integrated into the arrangement. These can be placed at the end or in the middle of the front row to maintain proper sight lines during instructor presentations. The entire front row could be comprised of standard height tables with tall tables incorporated in the second row, possibly eliminating the need for a tier, if enhanced flexibility is required. A limited amount of additional mobile chairs or stools may be considered around standard height tables for instructors to maintain informal communication by interacting in a seated position when working with these groups. Caution should be employed, however, to ensure that extra chairs do not impede the flow around table groupings.

General Considerations

The floor plan utilizes an area identical to the existing Tiered classroom with an additional 392 square feet dedicated to classroom storage. During focus groups, faculty revealed they prefer having "side space" where they can pull a student aside for semi-private conversations. Providing storage space that is easy for faculty and teaching assistants to flow in and out of can additionally support a spontaneous

Figure 6.

semi-private conversation without drawing attention to it. Back corners of the classroom, created by the curved table layout, can also serve this purpose. This area can incorporate whiteboard surfaces for peer teachers and instructors to pull out groups for impromptu collaboration as well.

Although the prototype classroom design utilized the same square footage as current classrooms, the long, rectangular shape makes it difficult to replicate in existing classroom buildings with spaces that tend to be squarer like. Employing this arrangement in existing spaces may reduce the number of groups per classroom, rendering it unfeasible due to administrative logistics. This model, however, could be adopted early in design for newly constructed learning spaces.

Conclusions

Focus group, observation, and survey data reflected previous findings correlating the efficacy of arrangements with anticipated activities by Brooks (2012) and others (Larsey et al., 2014; Lim Sok Mui et al., 2019; McDavid et al., 2018; Walczak & Van Wylen, 2013) with the unique ability to study the same students with the same teachers in two different classroom environments that afford active learning activities. As well as indicating classroom styles impact perceived engagement of students and teachers, findings also demonstrated that classroom design should afford flexibility to successfully accommodate a range of teacher and student-led activities. Additionally, this study suggests designers should carefully consider sight lines, encouraging eye contact in informal and formal interactions, which promote student-to-student and student-to-teacher engagement in the design of classroom space.

The identification of social engagement factors and classroom prototype were developed from a context specific inquiry; therefore, generalizability of results is a limitation of this study. Further research should be done to see if similar results are found in different contexts. Additionally, as is the case with proxemics, eye contact as a measure of attention in social situations may manifest differently in varied cultural contexts. More work could be done to better understand important cues for social attention in diverse cultural settings as well as populations who are visually impaired where eye contact may not be as impactful. Yet, the results from this investigation yield important, practical applications that can be applied to classroom design that accommodates varied teaching and student engagement activities.

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Appendix

Table 1. **Focus Group Results**	
Coded Response	**Supporting Quotes**
Eye Contact	<u>Design Studio</u> • "In this room they are looking in six different directions (looking at the monitors spread around classroom). They might be paying attention just as much but they're looking at the close screen which is not necessarily toward me." • "If you don't move around there are some students who you won't make eye contact with unless you stop and make sure and get all their attention" • "There is no opportunity for eye contact, there is no central focus" • "I don't know if I'm just seeing things happening more here or they're doing them more over here, like the texting." • "oh yeah, because the lack of eye contact would affect them too" • "They can't really hear or see me" • "I find [the counter-high tables] probably about the hardest part about teaching in that classroom… being on the shorter side and having the students up so high I worry about them being able to see where I am" <u>Tiered Classroom</u> • "When I am lecturing with the slides/Powerpoint, because they are facing me I feel like they are paying attention even if they're not." • "[In the Tiered Classroom] for me I can make eye contact. For me that's a major thing like I can see that you're seeing me and whether or not you're paying attention I know."
Behavior Setting	<u>Design Studio</u> • "I always said since it's so strong for collaboration, it makes it very hard for any kind of direct lecture or direct talking, even if you try and keep it to 5-10 minutes to get their attention you have to literally pull them out of the collaboration so it's a good thing, it's one of those mixed blessings, they want to talk to each other, they're facing each other, engaged, to pull them out of that engagement is a lot harder, where it's easier to get their attention in [the Tiered Classroom] and you do get that eye contact and you know" • "I think there's more shenanigans going on in there or at least we notice more, I always assumed that maybe we notice it more, but it might actually be there's more because we don't have as much physical presence, half of them are facing the other way most of the time" • "Maybe they can be more creative, but it makes it hard if there is something that needs to be done. It makes it really hard to lecture any bit at all in there." • "[In the Design Studio] they are at the same height with the higher chairs and they [TAs] have more informal conversations with the students." • "When I'm in [the Design Studio] I'm actively checking in and asking questions. Whereas in [the Tiered Classroom] I'm more driven by who's raising their hands." <u>Tiered Classroom</u> • "I see a lot more hand raising in there for help rather than like a wave or a 'Hi, can you help me?' as you see in [the Design Studio]. They raise their hands real high in [the Tiered Classroom]." • "That room does feel more like a classroom. Much more of what they're used to. And I think there is a different behavior in the students. There is more classroom behavior.
Movement	<u>Design Studio</u> • "I like walking around, I like that I'm not the center of focus in the room so there's more student to teacher interaction, I can get to the students easier" • "Access to students is much easier in that space" • "I feel more connected to the students because like they aren't just automatically looking at you so it makes me walk and be around them"

	• "You have to make a conscious effort to work the room differently." • "They [the students] just get up and walk to a TA or do other things to get the TAs attention" <u>Tiered Classroom</u> • "I find it very difficult to go across the back of [the Tiered Classroom]. It is narrow and they [students] put all their junk there so that lowers my interaction it keeps me pacing the front and moving up the middle aisle and back down." • "I feel like I give more attention to the students on the edges because you don't have to walk in to get to them" • "In [the Tiered Classroom] my peer teachers [TAs] sit in the four corners of the room and stay there. I have to remind them that I don't want you sitting down."

Table 4. **Student End-of-Semester Open-ended Question Results**	
Coded Response	**Student Quotes**
Peer-to-Peer Engagement	• "It was generally easier to **engage with my teammates** and other teams in [the Design Classroom] **because students faced each other** and could easily move about the room to interact with other teams." • "[the Design Classroom] was the best classroom out of the two because it was easy to communicate with other team members and work together." • "[the Design Classroom] is an excellent classroom for doing teamwork and working on a design, because of its layout, it makes it easier to communicate with my team members. But in [the Tiered Classroom], although it is a good classroom for lectures, I find it difficult to be able to interact with my team."
Learner-to-Instructor Engagement	• "It was generally easier to **engage with the professor** in [the Tiered Classroom] **because every student faced him/her.**" • "[The Tiered Classroom] was a great design for a team-working class like ENGR 131, while [the Design Classroom] was okay, it did not provide as much **engagement with the professor** as well as other teams."
Visibility and Orientation [Eye Contact]	• "I seemed to learn a lot better and did not get distracted in [the Tiered Classroom], as opposed to [the Design Classroom] because we were all **faced towards the professor**." • "I personally preferred [the Tiered Classroom]. It helped me focus better and I like the space more in general. It was much easier to pay attention as well because everyone is **facing the same direction**. In [the Design Classroom], even though there were multiple screens at my angle there were always pillars or **heads blocking the presentation**." • "In [the Tiered Classroom], the classroom has **seats all pointing to the front**, so it is difficult for teams to talk to each other. In [the Design Classroom], the instructor teaches in the middle of the room, which is **difficult for the students to see**. In addition, peer teachers are not stationed very close to students. It would be better if groups of four were all sideways facing each other and the instructor was at the front. That way, it would be relatively easy for **all students to see** the instructor properly." • "It is difficult to know **where to look** in [the Design Classroom], maybe if the professor walked around only one portion of the room."