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DEVELOPMENT ARTICLE

From swimming pool to collaborative learning studio: Pedagogy, space, and technology in a large active learning classroom

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Abstract To promote student learning and bolster student success, higher education institutions are increasingly creating large active learning classrooms to replace traditional lecture halls. Although there have been many efforts to examine the effects of those classrooms on learning outcomes, there is paucity of research that can inform the design and implementation process. This study investigates how spatial and technological features of a large collaborative classroom support active learning based on the Pedagogy-Space-Technology framework. The findings from our study suggest short lecture and class-wide discussion are essential in framing learning content before group activities, and connecting group outputs to the learning content after group activities. Through interviews, surveys, and focus groups, we found that-while small group activities are generally well-supported in large active learning classroomsfacilitating short lecture and class-wide discussion is key to the success of active learning in large classrooms. Technology should be carefully laid out in the space to accommodate those activities. Specific design and implementation suggestions and implications are provided.

Keywords Active learning classroom · Active learning space · Active learning · Collaborative learning · Technology integration · PST framework · Student-centered learning · Instructional technology

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Creating a large active learning space involves efforts from people with different expertise including classroom designers, architects, technology specialists, and instructional consultants who are focused on a question: how can intentional space design and technology enable a physical learning space to facilitate what was difficult or impossible in a traditional lecture hall? Lecture halls have worked for the teacher-centric, lecture-intensive instructional model. However, it is clear from the learning literature that students in passive lecture settings often do not learn as much as hoped, and a growing body of research on active learning strongly and consistently supports this claim (e.g., Beichner 2014; Freeman et al. 2014).

Early initiatives such as North Carolina State University's SCALE-UP, Massachusetts Institute of Technology's (MIT's) TEAL, and the University of Minnesota's PAIR-UP have consistently shown positive student outcomes in comparative studies (Beichner et al. 2007; Brooks 2012; Dori and Belcher 2005). Encouraged by positive outcomes, an increasing number of higher education institutions have adopted a large active learning classroom model (Beichner and Cevetello 2013). This trend of redesigning learning spaces to better support active learning approaches is predicted to continue, according the 2015 NMC Horizon Report (Johnson et al. 2015).

In response to similar curricular and instructional needs at a Midwestern university, a large, technology-enhanced active learning space has been built as an alternative to a traditional lecture hall. This space was originally a swimming pool and then later a map library, before being renovated as a large active learning space, called Collaborative Learning Studio (CLS, see Fig. 1).

This study investigates the instructional components and classroom activities that support active learning, and how spatial and technological features of the CLS reflect design and implementation processes based on the Pedagogy-Space-Technology framework (Radcliffe 2008).

The PST framework

The pedagogy-space-technology (PST) framework has been developed for the design and evaluation of active learning spaces in order to help stakeholders critically and holistically consider the three aspects and their interactions (Radcliffe 2008). The PST framework provides an inquiry-driven process to ensure stakeholders take a balanced approach grounded in pedagogy by asking questions related to types of learning and teaching in the space; space design, furnishings, and effective utilization of the space; and technology

Fig. 1 Swimming pool (left) to collaborative learning classroom (right)

integration and its effectiveness. The three components are interrelated, as illustrated in Fig. 2. Technology extends space and enhances pedagogy. Space that embeds technology encourages certain pedagogy. Pedagogy is enabled by space and enlarged by technology.

Active learning spaces are intended to support collaborative, active, learner-centered pedagogical approaches that are theoretically based on social constructivism–theories that emphasize meaningful social interaction as key to knowledge construction (Dillenbourg 1999; Littleton and Häkkinen 1999; Palincsar 1998). Related learning approaches include cooperative learning (Johnson and Johnson 2009), team-based learning (Michaelsen et al. 2002), collaborative problem-based learning (Barrows and Tamblyn 1980; Hmelo-Silver 2004; Savery 2006), and collaborative project-based learning (Bell 2010; Blumenfeld et al. 1991). The term active learning, as used in this article, refers to the wide range of instructional approaches that actively engage learners in the learning process rather than having them passively receive information from their instructors (Prince 2004). In active learning, student collaboration, cooperation, or discussion at the very minimum plays a central role in the learning process–which is why the term collaborative learning is often used to refer to active learning approaches (Prince 2004).

From the perspective of classroom design, collaborative learning involves two types of classroom activities: (1) small group or within group discussion, and (2) class-wide, cross-groups discussion. That is, instructors not only engage students in small group discussion but also ask students to share what they have learned with the entire class, provide feedback and encourage other students to give feedback, or compare and contrast different groups' processes and outcomes. For this reason, design decisions regarding space configuration and technology selection should be based on effectively and efficiently supporting these activities. Therefore, we examine to what extent space configuration and hardware technologies in four widely known enlarged active learning classroom models facilitate these two classroom activities.

Active learning classroom models

In this section, we briefly review four widely known and actively researched active learning classroom models that replaced traditional lecture halls: North Carolina State University's SCALE-UP, MIT's TEAL, the University of Minnesota's PAIR-UP, and the University of Iowa's TILE.

Although active learning has been around for a long time, the development of active learning spaces in higher education has generally moved from science, technology, engineering, and math (STEM) courses to multiple disciplines, and from very structured course redesigns to broadly supporting multiple disciplines and instructional approaches. The

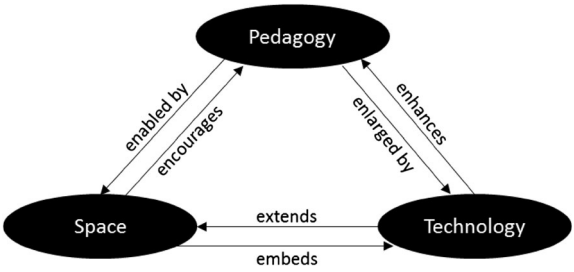

Fig. 2 The PST framework (adopted from Radcliffe 2008, p.13)

most widely-adopted and well-known active classroom model in higher education is SCALE-UP (Student-centered active learning environment with upside-down pedagogies), developed at North Carolina State University in the mid-1990s (Beichner 2014), which was originally focused on physics instruction and later expanded to other disciplines. Adopted by more than 150 institutions worldwide, the model reflects a flipped classroom pedagogy where students engage with the learning material and take quizzes before coming to class, and perform hands-on collaborative learning activities in class (Beichner 2014; Beichner et al. 2007). SCALE-UP helps instructors integrate experiments into courses in a studio-type physical learning space, where students can carry out labs in small groups while being coached (Beichner et al. 2007).

In an effort to improve attendance and failure rates in first year physics classes at MIT, the TEAL (Technology-Enhanced Active Learning) project team adopted the SCALE-UP model for large introductory courses. TEAL combines mini lectures, simulations, and hands-on desktop experiments in a collaborative learning format (MIT iCampus, n.d.). For desktop experiments, data is linked to student laptops where it can be visualized and simulated (Dori et al. 2003).

Based on the SCALE-UP and TEAL models, the University of Minnesota's PAIR-UP (Pedagogy-rich; Assess learning impact; Integrate innovations; Revisit emerging technologies) model takes an interdisciplinary approach to designing flexible classrooms that facilitate collaborative student-centered learning approaches (Whiteside et al. 2009). The PAIR-UP initiative's active learning classrooms are designed with the expectation of students bringing and using their own computing devices (Whiteside et al. 2009).

Built on the SCALE-UP model, the University of Iowa's TILE (transform, interact, learn, engage) initiative is an effort to transform teaching practices through faculty engagement in pedagogical changes to inquiry-guided learning, peer instruction, and in-class, team-based learning (Florman 2014; TILE: Transform, n.d.). The initiative takes a unique approach to expansion, providing pedagogical training for faculty members who will be developing new TILE courses and teaching them in the TILE classrooms (Florman 2014; Van Horne et al. 2012). Table 1 summarizes spatial and technological features of the major collaborative learning classrooms.

Previous research and knowledge gaps

The majority of the research that has been conducted has focused on student learning outcomes, engagement and perceptions of the learning spaces, and classroom activities. Consistently, students taught in active learning spaces have outperformed peers taught in traditional lecture-hall settings and showed positive attitudes and engagement according to student performance data (Baepler et al. 2014; Beichner et al. 2007; Brooks 2011; Dori and Belcher 2005; Van Horne et al 2012; Walker et al. 2011; Whiteside et al. 2010).

Nevertheless, there is paucity of systematic research that informs design and development of large active learning classrooms. More specifically, there is limited research on how and how well spatial and technological features of those spaces support various classroom activities. Previous research indicates that, although those spaces were designed to facilitate small group activities, lecture and class-wide discussion were regularly performed. However, some incompatibility issues with these two activities were reported (Brooks 2012, Van Horne et al. 2014; Walker et al. 2011). In this study, our research questions are: (1) what types of instructional components or class activities support active

Table 1 Spatial and technological features of large collaborative learning classrooms

Learning model	Classroom activity	Space	Technology
SCALE-UP	Small group discussion	Seven-foot round tables that seat nine students	Three laptops per table Ceiling-mounted projectors Portable group white boards Wall-mounted whiteboards
	Class-wide discussion	Instructor's station at the center	Wireless microphone Celling-mounted projectors Document viewer
TEAL	Small group discussion	Thirteen round tables that seat nine students	Three laptops per Table 13 whiteboards Eight screens on the wall
	Class-wide discussion	Instructor's station at the center	Instructor's display Eight wall projectors/screens Personal response system
PAIR-UP	Small group discussion	Round tables that seat nine students	Individual laptops Wall-mounted display technologies for students
	Class-wide discussion	Instructor's station at the center	Instructor's display Wireless microphones Wall-mounted display technologies for students Signal lamp at tables
TILE	Small group discussion	Round tables that seat nine students	Three laptops per table Nine wall-mounted LED monitors Wall-mounted white boards
	Class-wide discussion	Instructor's station at the center	Instructor's desktop, display, whiteboard, and wireless mouse Nine wall-mounted LED monitors

learning (including what a typical class day looks like in the CLS), and (2) how technology and space configuration of the CLS supports each instructional component.

Methods

Context: collaborative learning studio (CLS)

This study was conducted in fall 2013, when the CLS opened. Eleven undergraduate level courses were taught by a total of 10 faculty members (one taught two courses during the fall semester). Five faculty members personally requested the room through their departments, and departments or the Registrar assigned the other five to the room. Because the CLS was created out of the needs of the departments of anthropology and geography, priority scheduling was given to them. After satisfying their requests, the Registrar filled additional open class times based on other departments' needs for technology as well as room size and characteristics.

The courses taught in the CLS were 100 through 300 levels in disciplines including anthropology, arts and sciences, geography, sociology, and public health. Most classes met twice a week for 75 min, except one class which met once a week for three hours and

another class which met three times a week for 50 min. Student enrollments ranged from 26 to 86, with an average of 50. Faculty scheduled to teach in the CLS received training on the technologies from the campus teaching center. Instructors could also request one-on-one consultations about how to design a course that incorporates active learning approaches and how to better utilize room features to support those approaches.

The CLS is a large technology-enhanced active learning classroom space that was designed to facilitate active learning approaches in large classes. The CLS, takes advantage of state-of-the-art technologies to provide rich learning experiences for students in multiple disciplines. While some early active learning classroom projects were focused on supporting course redesigns in specific disciplines—namely physics for SCALE-UP and TEAL—the CLS was meant to be a space that could support a variety of active learning approaches across a variety of disciplines.

Figure 3 shows the layout of the CLS with technological features. The CLS has two levels: lower and upper classroom. There are a total of 16 student Tables (10 on the lower level and six on the upper level) with six chairs, a desktop computer, and two microphones at each table. The unique feature of this room is a 20-foot wide video wall in the front of the room in the lower classroom area, which was added to better facilitate class-wide and cross-group discussion.

The 16 panels of the video wall can simultaneously display the 16 student monitors using a gallery view. The video wall also accommodates the display of one large view or a quad view of four sources either from student monitors, desktop computers, laptop, or the document camera at the instructor's main station. Instructors can use their display control panels to select what to display, how to display (gallery view, quad view, or one large view), and where to display (the video wall, two projector screens, or student monitors). There are two control panels: one located on the lower classroom level near the instructor's

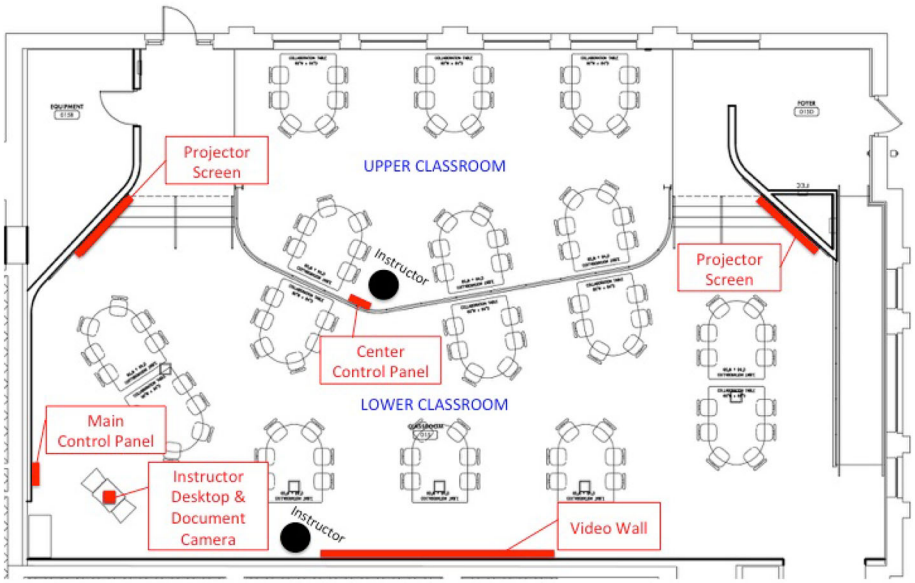

Fig. 3 Instructor's locations in the CLS

Table 2 Spatial and technological features of the CLS

Classroom activities	Space	Technology
Small group discussion	16 U-shaped tables that seat six students	Each student table contains: One desktop One LED monitor Connections for three laptops One document camera One portable whiteboard
Class-wide discussion	Instructor's stations in the front corner and the center	Video wall Two control panels Two wall-mounted projectors/ screens Speaker and two push-to-talk microphones at student tables Instructor's desktop and controls Instructor's wireless microphone

station and the other located on the upper classroom area. Table 2 summarizes spatial and technological features of the CLS.

After the first semester of operation, the following technologies were added in fall 2014 in response to faculty's feedback. At the student tables, document cameras, portable white boards, and speakers were added. Instructor's wireless microphone was provided to allow the instructor to move freely in the CLS.

Study design

In order to capture qualitative and quantitative dimensions of what was happening in the CLS, we chose to deploy and combine multiple forms of data collection in a convergent parallel mixed methods design (Creswell et al. 2007), validating findings through triangulating data from multiple sources (Johnson and Onwuegbuzie 2004). We collected data from faculty and students who used the CLS in fall 2013 regarding their teaching and learning experiences. Additionally, we conducted another survey in fall 2015 (fall 2015 survey) with faculty members who taught in the CLS in the fall and spring semesters of the following academic year. The purpose of this survey was to examine how often they used technologies that were added in fall 2014 as well as to ask additional questions about other technologies including the video wall.

Data collection

In fall 2013, we collected data through: (1) one-on-one semi-structured interviews with four faculty users of the CLS, (2) two focus group interviews with a total of 11 students, (3) online faculty survey, (4) online student survey, and (5) nine syllabi for courses taught in the CLS. Additionally, we sent another survey to faculty. Interview questions and survey items were developed to capture their uses and perceptions of the space and technology in classroom activities. Learning or student performance data was not collected given the purpose of the study. The authors and another researcher developed the questions together and went through several iterations of revision of the items. Table 3 presents data sources,

Table 3 Data sources, number of responses, and representation of the fall 2013 courses

Discipline	Level	Faculty interview	Faculty survey	Student focus group	Student survey	Syllabus
Anthropology	100	1	Anonymous[b]	1[a]	4	1
Anthropology	200				1	1
Arts and sciences	100	1				
Geography	100			1		1
Geography	200	1			3	1
Geography	200	1				1
Sociology	200					
Sociology	300					1
Public health	100			3		1
Public health	200			6*	17	1
Public health	300			1	15	1
Total	11	4	9	11	40	9

[a]A student who was enrolled in two courses taught in the CLS was counted for both courses

[b]Identifiers were not collected in the faculty survey

number of responses, and representation of the courses taught in the CLS in fall 2013. In fall 2015 survey, 10 out of 19 faculty members responded after teaching in the CLS in the academic year of 2014–2015.

Faculty interviews

Interviews with faculty aimed to capture information about teaching experience, implicit and explicit collaborative learning pedagogy, the use of the space and technology of the CLS for collaborative learning, and expectations and concerns related to use of the CLS. Faculty one-on-one interviews were semi structured. Questions include how they implement collaborative learning in the space, what were the most successful and the least enjoyable teaching experiences, how they perceive usefulness of the space and technologies, whether they have concerns or reservations about using the space, and what improvements can be made. See Appendix A for the full interview questions. Four faculty members were interviewed (3 women and 1 man).

Faculty online survey

The faculty online survey aimed to capture information about overall teaching experiences in the CLS. There were seven questions. Two were close-ended questions asking (1) whether the room was personally requested and (2) how many semesters they taught in the CLS. The remaining five questions were open-ended and asked what they do differently in the CLS, how teaching experience in the CLS affected their pedagogy, changes in student attitudes or behaviors, and what they liked and found challenging about the space. See Appendix B for the full survey items. The anonymous online survey was distributed toward the end of the semester, and nine faculty members responded out of 10.

Student focus groups

Focus groups aimed to capture overall student learning experiences in the CLS, their attitudes toward collaborative learning, and perceptions of the space and technology in relation to collaborative learning. Focus group interviews were semi structured. Questions include what a typical day is like in the CLS, how the instructor uses the space and technology, how they perceive effectiveness and value of collaborative learning, what are their likes and dislikes about the space and technology. See Appendix C for the full focus group interview questions. Faculty members were asked to distribute the invitation to their students. Eighty-four students volunteered, and 11 from five different courses were randomly selected based on their availability during the times when the CLS was open. Two focus group interviews took place with five and six students each in the CLS (9 women and 2 men).

Student online survey

The student online survey also aimed to capture information about overall learning experiences in the CLS. There were eight questions. Five closed-ended questions include frequency of technology use in the CLS (*used every class meeting, occasionally used, rarely used, and never used*), appeal of the technological and spatial features of the CLS, and helpfulness of the video wall and group activities in their learning (*a great deal*, *somewhat helpful*, and *not at all helpful*). Three open-ended questions include which activities worked best in the CLS, which activities worked least well in the CLS, and how the room helped or hindered learning. See Appendix D for the full items. The faculty members were asked to distribute the survey link to their students near the end of the semester. This survey was anonymous except for a course identifier, and 40 students from five courses responded.

Syllabi

Nine faculty members provided course syllabi for the fall semester. The syllabi provided a better understanding of course objectives, class structure and activities, course schedule, and assessment structure.

Fall 2015 faculty survey

The additional fall 2015 faculty survey aimed to capture frequency of usage of the added technologies as well as specific uses of the video wall. The survey was comprised of 12 questions. We asked how often they used added technologies such as document cameras, microphones, portable white boards, speakers, and instructor's wireless microphone. Additionally, we asked how often they used the push capability of the video wall and how frequently each view of the video wall was used in displaying lecture materials, comparing student work, monitoring student work, and displaying a combination of instructor and student materials (*used every class meeting, once every few class periods, a few times during the semester, and never used*). We also asked about their perception of video wall effectiveness for class-wide discussion and monitoring student group work (*very effective, somewhat effective, somewhat ineffective, very ineffective*) with an option of *not used for*

the purpose. See Appendix E for the full survey items. The survey was distributed to 19 faculty members who taught in the CLS during the 2014–2015 academic year.

Data analysis

The PST framework structured our analysis of qualitative and quantitative data. Qualitative data included faculty interview data, student focus group data, syllabi, and responses to open-ended questions in the three surveys. Quantitative data include responses to closed-ended questions in the survey. Our analysis centered on the qualitative data, especially recordings and transcriptions of the faculty interview and student focus group data. Then, we analyzed the quantitative data using descriptive statistics and histograms. There were four phases of data analysis: (1) initial review of each dataset and organization of the qualitative data based on the PST framework, (2) identification of codes and coding the qualitative data, and (3) inter-rater reliability check, and (4) combination of the results of analyzing the entire datasets (including the quantitative data from the surveys) to support emerging themes.

Initial review and organization based on the PST framework

Initial review of the data included segmenting based on a central meaning of accounts, annotating each segment with a summary of the central meaning, and organizing the segments based on the PST framework. Segments refer to one or more phrases or sentences that contain one central meaning of accounts., 201 segments were identified. From the PST framework, we identified the following categories: (1) Pedagogy, (2) Space, (3) Technology, (4) Interaction between Pedagogy and Space, (5) Interaction between Pedagogy and Technology, (6) Interaction between Space and Technology, and (7) Interaction among the three.

Coding and reorganization

The second phase entailed identifying codes and coding the data based on the seven categories. For each category, appropriate codes of the category were given. For example, if Pedagogy-Space was selected for a segment, the researchers needed to select codes from Pedagogy and Space. The coding scheme was progressively developed.

Inter-rater reliability check

Around 10% of the 201 segments, 21 segments of qualitative data were purposively selected to check for inter-rater reliability. These segments were selected based on their significance to the study as containing central themes of the study findings. See the segments in Appendix F. There were two rounds of coding: (1) deciding among the seven categories based on the PST framework, and (2) deciding on codes under each category of PST. For both rounds, each of the three researchers coded the segments individually and the codes were combined and compared.

At the first round, out of 21 coded segments, the three researchers agreed on 11 segments, two of them agreed on eight segments, and none of us agreed on two segments. The researchers discussed the disagreed segments until reaching consensus on all of them. As a result, a couple of changes were made to the coding scheme during the process: (1) adding

the group presentation component to the code, *class-wide discussion* in Pedagogy, and (2) creating another code, *lighting* to Space.

The researchers performed another round of coding based on the agreed PST categories. This time, the researchers were supposed to decide on a set of codes for each category. For example, if Pedagogy-Space was selected for a segment, the researchers needed to select codes from Pedagogy and Space. So, one segment was given multiple codes. Out of total of 42 codes, at least two of the researchers agreed on all. There were 28 codes that all three agreed on. The researchers discussed until reaching consensus. As a result, one change was made to the coding scheme: adding instructor-led reflection on group activities to the code, *class-wide discussion* in Pedagogy.

Approximately 78% of the qualitative data was categorized based on the PST framework. The data excluded contained introductions of the study purpose, the interviewer, and focus group participants, the interviewer's clarifying questions, and unrelated conversations. Of the 78, 24% of the elements were categorized as Pedagogy–Technology, and 20% were categorized as Pedagogy-Space. Table 4 shows all of the category percentages.

Combination of the data analysis results of the entire datasets

The final phase entailed combining the analysis results of the quantitative data into the analysis results of the qualitative data, which helped us triangulate the data. Survey questions related to each sub theme were incorporated in order to generate a rich story and valid claims. The syllabi were analyzed based on course activities, assessment structure, and course schedule to supplement the other data.

Final coding scheme

A coding scheme was developed and refined progressively during the data analysis, as a new code needs to be added. All of the codes were straightforward as they refer to specific objects. Table 5 presents the codes and corresponding definitions.

Results

This results section is organized based on the PST framework. Our discussion starts from pedagogy entailing instructional activities on a typical class day and continues how each instructional activity is supported by technology and spatial configuration of the CLS.

Table 4 Coding matrix

Category	# of Segments	Percentage
Pedagogy	39	19
Technology	12	6
Space	17	8
Pedagogy—Space	40	20
Pedagogy—Technology	49	24
Space—Technology	16	8
Pedagogy—Space—Technology	29	14
Total	202	100

Table 5 Definitions of codes

Category	Code	Definition
Pedagogy	Lecture	One way or interactive lecture by instructor
	Group activity	Small group activities or discussion among students
	Class-wide discussion	Class-wide, cross-group discussion led by instructor or students, group presentation, and instructor-led reflection on group activities performed
	Individual activity	Individual instructional activity
	Movie	Movie or other audio-visual presentation
Space	Spatial configuration	Arrangement of furniture and technologies
	Student table	U-shaped student tables
	Movable chair	Wheeled student chairs around tables
	Main station	Instructor station in front right corner of CLS, with desktop and a main display control panel
	Center	Center of the room between the two levels, with additional control panel
	Lighting	Natural lighting from windows
Technology	Video wall	Video wall in front of CLS that can be viewed as one large view, quad view, and 16 panel view
	Main control panel	Panel in the main station for control of displays
	Center control panel	Another control panel in the center of the CLS
	Push capability	The capability to push instructor desktop to student monitors or bring student desktop displays to the video wall or other displays in the room
	Displays	Video wall, two projector screens, and 16 student monitors
	Instructor desktop	Instructor's desktop in the main station.
	Instructor microphone	Wireless instructor microphone
	Instructor document camera	Instructor's document camera in the main station
	Student desktop	Student desktops on the student tables
	Student monitor	Monitors connected to student desktops on the student tables
	Student microphone	Push-to-talk microphones on the student tables
	Student document camera	Document cameras on the student tables

Pedagogy: instructional activities

Four collaborative learning patterns were identified in the 10 courses the collected data represent. Half of the courses had short lectures and group activities followed by class-wide discussion across groups. The rest had lecture and group activities with or without using computers. Table 6 summarizes the instructional flow and course structure in the CLS.

Table 6 Instructional flow in the CLS

Instructional flow	# of Courses
Lecture—group activities—class-wide discussion	5
Lecture—group activities almost daily	3
Lecture—group activities once in a while	1
Group activities—class-wide discussion	1

Lecture

In most of the courses, even where collaborative learning was prevalent, lecture was an essential instructional component. Instructors stated during the interviews that they used lecture to communicate main ideas clearly before and after group activities, framed learning content for students, and invited guest lecturers whose work was important for students to learn.

Group activities

Every course had group activities at varying frequencies. In the faculty survey, eight of 10 respondents shared that they incorporated more group activities into class than before. Group activities varied among courses. One geography course used a textbook with computer-based group activities that students completed at the end of each chapter. In another course, group activities were structured based on a specialized geographic software program. In an anthropology course, computers were used to collect and analyze data, find resources, and write a group report. Non computer-based group activities included group discussion based on discussion points or questions provided by instructors, paper-based group activities, and physical group activities where students moved around. Some group activities were daily and others lasted for several weeks.

Class-wide discussion

Class-wide discussions frequently began with a group presentation, followed by instructor or student comments. By collecting outputs from each group and combining the results, the class could compare one group's output with another, or connect group activities to the lecture through instructor or student comments. Class-wide discussion was an important component of collaborative learning, where students could reflect on their own group activities and connect their group work to the course content. Three students from two courses with no such component stated they were unsure what they learned from group activities or how group work related to course content.

Best and least ranked learning activities

Table 7 presents learning activities that worked best and least well in the CLS and the reported rationale for the responses according to the student survey. A total of 29 students responded to the corresponding survey questions, and 23 mentioned group activities as working best, while 11 students reported lecture as working least well. For the best activities, all of the comments related to technology in the room. On the other hand, the

Table 7 Learning activities that worked best and least well as reported by students

Pedagogy	Technological and spatial features	
Learning activities	Worked best	Worked least well
Lecture	n = 7 • Student monitors (4) • Video wall (3)	n = 11 • Too many screens (2) • Distracting (2) • Can't see instructor (1)
Group activities	n = 23 • Student desktops (9) • Push capability (1)	n = 1 • Being forced to do group work (1)
Class-wide discussion	n = 5 • Push capability (3) • Student microphone (1)	n = 3 • Hard to hear and can't tell who was talking (1) • Being able to interact with everyone (1)
Individual work	n = 0	n = 5 • Hard for the instructor to be on a personal level (1) • Not a proper space for individual work (1)

Note N = number of students

rationale for the activities that worked least well was complicated by factors like pedagogy, space, and technology.

Table 8 presents faculty reporting of effective room features and challenges to teaching in the room. Nine faculty members responded, with most positive comments about effective room features for group activities. Comments about challenges were mostly related to lecture.

Technology and spatial configurations for lecture

Lecture was the activity that students and faculty reported as working least well. Of the 29 respondents, 23 chose lecture to be the least well supported activity, while seven chose

Table 8 Effective room features and challenges to teaching reported from the faculty survey

Learning activities	Effective room features	Challenges to teaching
Lecture	Multiple image capability (1)	Need a pointer technology (1) Need a secondary instructor desktop in the center of the room (1) No place to see everyone (1)
Group activities	Student Tables (6) Student monitors (2) Movable chairs (2) Student desktop (1)	Need speakers at student Tables (1) Need technology that facilitates students' quick hand writing (1)
Class-wide discussion	Push capability (2) Student microphones (2)	Need technology that facilitates sharing students' handwritten notes (1) Can't spot students raising hands (1)

Note (Number of faculty survey respondents)

lecture to be the best supported one. All four faculty interviewees reported difficulty with lecturing in the classroom. In the survey, one faculty member specifically mentioned that it was hard to do lecture, and five others reported room incompatibility with lecture. In addition, two students in the focus group said lecture-heavy classes might benefit more from being in a lecture hall. Overall, the technology worked well for lecture, but there were some issues with the spatial configuration of the room that made seeing and hearing lectures more difficult.

Technology

The seven students who mentioned lecture as the best learning activity cited the various display technologies in the CLS as a reason. The giant video wall enlarged lecture content for student viewing, while the student monitors displayed the lecture material up close.

Video wall

According to the student survey, the video wall was used almost every class for displaying lecture materials. The class means of the frequency question ranged from 3.7 to 4 with four being *used every class*. According to the fall 2015 faculty, all ten faculty respondents used one large view every class, mentioning the video wall was particularly great for showing a Google Earth tour, watching a movie, and close analysis of intricate work such as stitches in a textile. On average, quad view was used once in a while. One instructor used quad view every class, while three instructors used quad view once every few class periods. The 16-panel gallery view was used much less frequently.

Some minor issues with the video wall included the laser pointer now showing on the video wall, difficulty with diagramming, poor quality of projection on the video wall because of image enlargement.

Nevertheless, one instructor mentioned that the capability to draw different materials and display them made lecturing more effective, stating "I have used the multiple image capability to show fresh plant material with the doc cam on the video wall, while a power point presentation is on the student monitors." Related to this, some faculty respondents (faculty survey, $n = 1$; fall 2015 faculty survey $n = 3$) noted they would utilize dual displays more than smaller views. One of them specifically mentioned 16-panel view being too small, and a 2×4 configuration being more optimal.

Student monitors

The majority of faculty displayed lecture materials on student monitors. According to the fall 2015 faculty survey, eight of 10 respondents did so every class and the other two once every few class periods. Students expressed mixed feelings about it depending on which display they preferred watching for the lecture material. Those preferred the video wall mentioned that having too many student monitors in view was sometimes distracting during lecture especially when students sat near the back of the CLS. On the other hand, some other students mentioned that it was one of the best features of the room. A student who preferred watching presentations on the student monitor, said "it's definitely more vivid on the monitors themselves." Also some students suggested having dual displays to display lecture material and group work simultaneously on their desktop monitors.

Wireless instructor microphone

A wireless microphone enabled the instructor to move freely in the room. Half of the respondents used it every class, one a few times during the semester, and four never, according to the fall 2015 faculty survey.

Spatial configuration

Spatial configuration was found to be not very compatible with lecturing. Because the CLS was designed for small group activities, there was no central location for an instructor to stand and lecture. In a lecture hall, the seats were gathered around the front of the room so everyone faces the instructor. However, in the CLS, students gathered around group tables, and the instructor walked around the tables. Consequently, there was no central place where the instructor could see everyone and be the focal point of the classroom. Five instructors mentioned this as a challenge. Two students reported another issue: Room technology was stationery and instructors could not control it while moving around. In the end, the instructors ended up lecturing from either (1) the front of the room where the main station and video wall were, or (2) the center of the room in the upper level where the center control panel was located. The black circles in Fig. 3 show the locations. However, neither spot was perfectly compatible with lecture.

The front

A major issue with the front as a lecture spot was sightline and distance from some students. Obstructive monitors made it hard to capture students' attention or spot raised hands. With student monitors in the way to the front, students also found it difficult to concentrate on the lecture (Student focus group, $n = 2$), one saying "all the TVs having his Power Point up and it is really distracting. I'm back there, so I see eight or nine". In addition, four students also mentioned it was hard to see their professors, who sometimes missed raised hands. Also, a student sitting in the back could not see what the professor was pointing at in the video wall.

The center

The center of the room in the upper level served as another lecture spot. Using the center control panel, the instructor could minimize the distance from students and have some level of control over the display devices. However, two problems were identified. First, being away from the main station with the instructor desktop and document camera posed a major challenge. The instructors complained that they had to go to the main station in the front of the room to change what was displayed or to show diagrams using the document camera. This disrupted the flow of the class, and two students mentioned it made the situation awkward for both instructor and students. To overcome this limitation, a teaching assistant at the main station controlled the instructor desktop during lectures as verbally directed by the instructor. However a student reported the verbal directions were distracting. Second, the instructors still had a problem of not being able to see every student or be seen by every student despite of being in the center of the room.

Technology and Spatial Configurations for Group Activities

Students and faculty rated group activities as working best in the room. Movable chairs combined with student desktops and monitors in the U-shaped student tables facilitated group activities—particularly computer-based group activities. Faculty interviewees appreciated the positive team building experience, describing the room as "a classroom environment that allowed for the teams to function as a unit interacting with other teams."

Technology

Student desktop computers

Based on the student survey, desktop computers were the most frequently used technology. Table 9 presents frequency of student computer use for group work. Forty students from five courses reported using it every class or at least occasionally. Seventy-five percent (n = 30) of student survey respondents selected technology on the student tables as an appealing room feature. Students and faculty found the desktops particularly useful for group activities such as collaborative writing or analysis, or using domain-specific specialized software programs (faculty interview, n = 1; faculty survey, n = 3; student survey, n = 9). In implementing group activities, two faculty interviewees commented that it was essential to have teaching assistants help address technical issues and keep things moving. One mentioned needing a teaching assistant for every four groups, and how peer instructors "serve a pivotal role there because they're safe in terms of asking questions…"

On the other hand, at times student desktops were not very helpful (faculty survey, n = 2; student focus group, n = 1). A faculty interviewee mentioned potential distraction from face-to-face interaction, and another mentioned incompatibility or inefficiency for group activities that involved quick sketches. A student from a lecture-heavy course was disappointed at the instructor underusing technology and not taking advantage of it for collaborative learning.

Video wall

Instructors preferred using the video wall to display one view followed by the quad view which allows instructors to simultaneously show the work of up to four groups of students according the fall 2015 faculty survey.

Half of the respondents said the video wall was somewhat yet not very effective for monitoring group activities because: (1) some preferred visiting each group in person (n = 5), (2) some were not using computer-based group activities (n = 3), (3) the 16 panel

Table 9 Frequency of use of student desktops for group work from the student survey

Discipline	Level	N	Mean	SD	Min	Max
Anthropology	100	4	3.8	0.5	3	4
Anthropology	200	1	3.0	n/a	3	3
Geology	200	3	3.7	0.6	3	4
Public health	200	17	3.7	0.5	3	4
Public health	300	15	3.7	0.5	3	4
Total		40	3.7	0.5	3	4

Note 1 Never used, *2* Rarely used, *3* Occasionally used, *4* Used every class meeting

view was too small to see (n = 1), and (4) some did not want students to look at other groups' answers (n = 1).

Other technological needs

Other comments noted needing a teaching assistant to resolve technological issues (faculty interview, n = 1), technology to facilitate quick handwriting for math types or chemical symbols (faculty survey, n = 1), and speakers at student tables to analyze audio clips. To address these needs, portable whiteboards and speakers were added to the student tables in fall 2014. Based on fall 2015 survey responses, at least three faculty respondents used portable whiteboards at least once every few class periods. This rate (3/10 = 30%) is higher than that for faculty from the chemistry and mathematics departments (4/19 = 21%). Three respondents out of 10 used the speakers at least once every few class periods (30%). This also exceeds use by the auditory course (1/19 = 5%).

Spatial configuration

Student tables

Students reported the most appealing feature of the room is group tables (n = 33, 82.5%). Students and faculty agreed that the tables made it easy to do group activities (focus group, n = 6; faculty interview, n = 2; faculty survey n = 6). A faculty member said:

> The most important design element is the tables that break up a large class into many smaller clusters. This personalizes the experience at an appropriate human scale and the effect has been that students carry their engagement outside the classroom and talk to one another about what they are learning.

Students also liked that the table provided plenty of workspace and room for everyone's textbooks, notebooks, and laptops (Student focus group, n = 8) and that the U shape means everyone is facing everyone else (Student focus group, n = 2).

Other comments

Another appealing feature was comfortable movable chairs (Student survey, n = 30, 75%; Student focus group, n = 1). Some students liked being able to swivel around and look at the instructor (Student focus group, n = 3). Two instructors liked movable chairs. However, one student mentioned that there was not enough space for physical group activities where everyone had to stand up and move around.

Technology and spatial configurations for class-wide discussion

Students and faculty had mixed feelings about how the room supported it. Most were positive about technology such as the push capability and student microphones (Faculty interview, n = 3; Faculty survey, n = 4; Student focus group, n = 6; Student survey, n = 4). However, spatial configuration presented some issues with class-wide discussion (Faculty interview, n = 3; Faculty survey, n = 1; Student focus group, n = 5; Student survey, n = 1).

Technology

Push capability and video wall

The most frequently mentioned technology for facilitating class-wide discussion was the push capability. Seventy-three percent of student respondents chose it as an appealing feature (n = 29), and the five courses they represented used it occasionally as shown in Table 10. Three instructors commented that push capability was most useful for class-wide discussion and that multiple views of the video wall enabled them to see student work process and output in depth, combining results or outputs from each group, and comparing group results side by side on the video wall in the fall 2015 survey. Six students noted that seeing the differences and similarities among groups visually helped and facilitated their learning.

Eight out instructors thought the push capability was effective for comparing student work for class-wide discussion. The respondents commented that it was an efficient way to display student work (Fall 2015 survey, n = 2); made it seamless to transition from one group to another, maintaining the momentum of the discussion (n = 1); and provided a way to check student understanding, give immediate feedback, and build on the discussion (n = 2).

The one view was most frequently used, the quad view nearly as frequently used, and the 16-panel view least used in comparing student work. Two respondents specifically mentioned the 16-panel view being too small to be legible from the back. A faculty interviewee preferred quad view to 16-panel view because it was more readable during discussion. Two respondents mentioned even the quad view was distracting, one preferring a dual view with 4 by 2 configuration of the video wall, which could make the displaying content larger than in the quad view. Few instructors displayed a combination of instructor materials and student work. One instructor wanted to simultaneously project student work and instructor material side by side.

Other technologies

Other technologies for facilitating class-wide discussion included student monitors, student microphones, and document cameras in the student tables. About student monitors, some students suggested having a split screen display or dual monitors to display their own group work and the instructor's input (Student focus group, n = 2). Student microphones were used at least a few times during the semester. Student document cameras were rarely used.

Table 10 Frequency of use of video wall for presenting student work

Discipline	Level	N	Mean	SD	Min	Max
Anthropology	100	4	3.5	0.6	3	4
Anthropology	200	1	3.0	n/a	3	3
Geology	200	3	3.3	0.6	3	4
Public health	200	17	3.5	0.6	2	4
Public health	300	14	3.1	0.5	2	4
Total		39	3.4	0.6	2	4

Note 1 Never used, *2* Rarely used, *3* Occasionally used, *4* Used every class meeting

Spatial configuration

Class-wide discussions shared the same incompatibility issues as lectures. There was no centralized place where everyone could see the instructor, and where the instructor could have full control over the technologies. As one faculty interviewee pointed out, "discussion was disembodied because students could not see the person talking." Some also said this was annoying (Student focus group, n = 5), and one of the three students who picked class-wide discussion as working least well stated this as the reason. One student suggested having a signaling lamp at each table to indicate where the speaker is.

Other comments about space and technology

Students found spaciousness of the room and natural light from windows appealing (Student survey, n = 32, 80%; n = 24, 60%, respectively). The large space made students feel comfortable and relaxed, especially with heavy technology in the room (Student focus group, n = 4). However, students sitting in the corner felt disconnected and distracted (Student focus group, n = 3), which was alleviated by their instructor walking around to check on them (Student focus group, n = 1). Some students also said the abundant natural light from windows helped them stay alert and made the class enjoyable (Student focus group, n = 4). However, poor air circulation meant the space heated up when many people were there and took a while to cool down (Faculty interview n = 2, Student focus group n = 3).

Student learning experiences

Generally, students perceived the CLS to be helpful in their learning (Student survey, n = 25), but some students felt it hindered their learning (Student survey, n = 7). Those who perceived it to be helpful commented that discussing learning content with other students and asking questions helped them learn better (Student survey, n = 14; Student focus group, n = 5). They also liked that the video wall provided visual aids for their learning (Student survey, n = 10), especially when viewing other groups' work side by side (Student survey, n = 4). In addition, some students said they enjoyed having a different classroom set up and instructional approaches in the CLS (Student focus group, n = 3). One said, "I think it's a nice little getaway …because all my other classes it's just a big lecture auditorium or just a regular classroom, so this is really different compared to anything else I've been in."

Three major reasons students perceived the CLS hindering their learning follow. First, the room was too large for them to connect with their instructor or students in different groups (Student survey, n = 7). These students came from classes with enrollment of 36–86. Second, some students struggled to see how group activities pertained to learning content (Student focus group, n = 1) or did not have regular class-wide discussions for reflecting on or connecting group activities to learning objectives (Student focus group, n = 3). Third, students who were in lecture only classes felt disappointed and thought it was waste of classroom resources (Student focus group, n = 2).

Students also liked when everyone contributed to group activities (Student focus group, n = 1), and when group activities did not extend outside the classroom (Student focus group, n = 1). They did not like group activities when everyone did not participate equally

(Student focus group, n = 3). There were more students who liked to stay in the same group (Student focus group, n = 6) than those who preferred switching groups (Student focus group n = 2). Those who liked to stay noted the group process became more efficient as they got to know each other and built closer relationships that extended outside the classroom. On the other hand, students who preferred switching groups said they did not want to be stuck with people who did not participate, or they wanted to make more friends or hear various perspectives.

Limitations

This study bears some limitations. First, most of the data are self-reported data. It is possible that there was some discrepancy between what participants reported and what they actually thought or did. Conducting direct observations of classes in session would have alleviated this problem. Also, direct observations may have yielded richer data on how the CLS was used and what instructional activities took place.

Second, although the faculty members were well represented, the students' response rate was low and several of the courses were not represented. Four courses out of 11 were not represented, and two disciplines that were not represented were (1) arts and science and (2) sociology. It should be noted that the findings do not represent students' perspectives from the courses in the disciplines.

Implications

The study provides a detailed qualitative description of how active learning was implemented in large undergraduate classes, and how technology and space supported it based on the PST framework. The findings of the study contribute to active classroom design and implementation.

Most active learning classrooms are designed primarily to facilitate small group activities and do not take lecture or class-wide discussion into consideration. However, a closer look at typical class activities–and the essential roles lecture and discussion play–emphasizes the importance of flexibility in classroom design. Most classes include some lecture to communicate main ideas and structure learning content, as well as small group activities and class-wide discussion to consolidate results and instructor feedback. The presence of these instructional components aligns with previous research findings for other active learning classroom models (Brooks 2012; Van Horne et al. 2014; Walker et al. 2011). Our findings are consistent with previous studies while also pointing out the challenges of class-wide discussion and lecture in large active learning spaces.

Overall, room technologies like the video wall and student desktops were perceived to be useful for lecture and class-wide discussion. Students and instructors found it particularly helpful to display multiple sources at a time on the video wall, although they thought an effective pointer would add value. Faculty and students wanted a dual display for comparing two sources in larger views on the video wall and student desktops.

The current space configuration posed some challenges for lecture and class-wide discussion, mainly with respect to line of sight. Our research findings suggest that a centralized station is essential to allowing an instructor to capture every student's attention and provide control and access to classroom displays including the document camera. A faculty member suggested having movable desks or a space in the center of the room to let students face instructors or guest lecturers, or provide some means for lowering student monitors to secure a clearer view.

Also, mobile technologies would help free up instructors and allow them to engage class in class-wide discussion from anywhere in the room. For example, a wireless mouse or keyboard would provide more control over the instructor desktop as implemented in large TILE classrooms (TILE: Transform, n.d.). A mobile application such as Doceri would support increased instructor mobility during lecture or discussion by enabling desktop control and white boarding at a distance.

To facilitate class-wide discussion, students had several suggestions such as having personal or team response systems, setting up signaling lamps at student tables, and having split or dual monitors. Personal or team response systems used in TEAL classrooms can instantaneously collect and display students responses (MIT iCampus, n.d.). Signaling lamps at student tables implemented in PAIR-UP's ALC may help students locate the speaker, preventing the discussion from being disembodied, or help instructors spot students who want to speak (Office of Classroom Management of the University of Minnesota, n.d.). Having split monitors or dual monitors lets students simultaneously view their own group work and instructor materials, as shown at Michigan State University (Lee et al. 2014).

In addition, ongoing pedagogical and technological support is needed for successful implementation that maximizes use of the space. Two instructors mentioned that one-on-one consultation sessions at CITL were helpful. One suggested having online pedagogical resources to consult instead of having to physically visit CITL during a busy semester. All faculty interviewees unanimously agreed that having teaching assistants was critical in running large classes with active learning approaches. Assistants can answer student questions, facilitate group discussion, help with spotting students who raise their hands, and controlling technology in the main instructor's station.

Table 11 Design suggestions and implementation implications

Design suggestions	Implementation implications
Flexible spatial configurations for lecture and class-wide discussion	Ongoing pedagogical and technological support
• Centralized instructor's station in a half circle configuration • Movable desks and a center space to gather around • Monitors that can retract into tables • Mobile technologies that free up instructors and enable whiteboarding • Video wall • Dual display • Pointer technology • Student tables • Signaling lamps • Dual monitors	• Online pedagogical resources and ideas • How to implement the ideas using the technologies • Time to explore the technologies • Teaching assistants • Spotting students raising hands • Consulting with small groups • Controlling instructor's desktop, etc.

All faculty interviewees indicated that it took some time for them to get used to in-room technologies, and the one-hour training at the beginning of the semester was insufficient. They wanted to have enough time to explore the technologies before and during the semester to figure out how to implement new pedagogical approaches. They especially wanted to figure out how to maximally utilize the video wall and push capabilities. Some students also mentioned that instructor technological knowledge helped with running classes smoothly (Student focus group, n = 4). In addition, timely technical assistance and troubleshooting were important. According to some students, if a technical issue was not fixed in time, instructors ended up doing something else and losing momentum (Student focus group, n = 2). Lastly, some faculty wanted more concrete ideas of how in-room technologies and software applications can be effectively integrated into classrooms (Faculty interview, n = 1; Faculty fall 2015 survey, n = 1). Table 11 summarizes feedback.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix A: Faculty interview questions

Semi-structured interview aimed at capturing instructor insights related to beginning of semester themes following a semester of teaching in the CLS.

Possible questions and follow-ups

We would like to hear about your experiences teaching in the CSL this semester.

1. For the class you were teaching, what do you feel worked particularly well in (or about) the room? **OR** Are there some success stories you can share with us about your teaching in the CSL this semester?
    a. What, specifically, about the room do you feel may have enhanced teaching and learning?
    b. Is there anything about the space that you think may have interfered with, or detracted from, teaching and learning?
2. What kinds of problems did you run into over the course of the semester?
    a. Were these problems able to be addressed/resolved to your satisfaction?
3. What were your impressions of student experiences in the space?
4. What kind of impacts do you think the space may have had on student learning?
    a. Were there noticeable differences between different types of learners?
5. Did you make any unanticipated changes in your approach to teaching this course, as a result of being in this space? **OR** How did teaching this course in the CSL compare with teaching the course in other spaces?

a. What was different?
b. What stayed the same?

6. What kinds of courses do you think are best suited to this space? **AND/OR** Are there courses that you think would not work well in the CSL?
7. What would make this space better? **OR** What ideas or wishes do you have for improving the CSL?
8. If you could return to the beginning of the semester and be able to teach this course over again, knowing what you now know about working in this space—would you do anything differently, and if so, why?
9. How has your experience in this space impacted your beliefs about teaching and learning?

   a.
   How has this experience influenced your plans/approaches to teaching in more traditional spaces?

10. How would you characterize the support/training you received for working in the CSL?

    a. What was helpful? **OR** What was most helpful?
    b. What could you have used more help with? **OR** What could you have used more support with/for?

11. What advice would you give to instructors preparing to teach in a space like this?

Appendix B: Faculty online survey

Please focus your responses on your experiences teaching in the Collaborative Learning Studio.

1. Did you personally request to teach in this classroom?

   Yes
   No

2. Including this semester, how many semesters have you taught in this classroom?

   1 semester
   2 semesters
   3 semesters
   4 semesters
   5 semesters
   6 + semesters

3. What are you doing differently in this classroom that you haven't done (or couldn't do) in other rooms?
4. If you have changed any aspects of your teaching because of your experiences in this classroom, which, if any, of those changes have you taken back to other classroom settings?
5. Have you noticed any changes in student attitudes or behavior that you think might be attributable to this classroom or how you've changed your class because of the space?

What are those changes, and how do you think the classroom directly or indirectly led to them?

6. We built this classroom in part to test out new classroom design elements. What elements of this classroom would you most like to see carried forward into new classroom designs? Why?
7. Please share any challenges to teaching in this classroom that you think we should keep in mind as we consider renovating other classrooms.

Thank you for your valuable input. Once we compile the results of this survey, we might have more questions that would be best addressed by a focus group toward the end of the semester. We hope that you will consider joining that in-depth conversation, should you receive an invitation later this spring.

Appendix C: Student focus group questions

Focus group will be aimed at capturing student attitudes and impressions regarding both the aesthetics and actual pedagogical practices in the CLS. It will also attempt to capture implicit/idiographic theories of learning and attitudes toward collaborative pedagogy and technology use in the classroom.

Possible questions and follow-ups

We are interested in learning about the experiences of students in the new CLS space

1. Could you please describe what a "typical" day in your class is like? **OR** How does your instructor use the CLS?
    a. What other learning activities have you've participated in/experienced in the CLS?
        i. What are those activities like for you?
            1. How helpful/effective would you say they are?
2. What do you like and/or dislike about the space?
    a. Can you recall what your first impressions of the room were?
        i. What stood out to you about the room?
    b. What do you think works particularly well in the room?
    c. What isn't working in the room? **OR** What would make the room better?
3. What differences do you notice between the CLS and the other spaces you attend classes in?
    a. How might the differences you notice be impacting your learning?
    b. Are there differences in how attentive or distracted you are? If so, what do think might be responsible for those differences?
4. Are there classes you are taking that would not work in a space like the CLS? What are they, and why do you think they wouldn't work in there?

5. What experiences have you had previously with collaborative learning approaches?
    a. What were those experiences like? **OR** How did you feel about those experiences?
    b. Do you feel like collaborative approaches make a difference for your own learning?
        i. In what way? **OR** Why or why not?
6. How do you learn best? **OR** Thinking back over all the experiences you've had as a student, tell me about the class (or classes) that you feel you learned the most in.
7. How do you feel about the use of technology in classrooms?
    a. What experiences have you had with different learning technologies?
    b. What do you see as pros and cons of using technology in the classrooms?
    c. What difference, if any, has technology use made for your learning?
    d. What have been the most helpful/least helpful applications of classroom technology that you've experienced?

Appendix D: Student online survey

This survey asks about your experience in the Collaborative Learning Studio (SB015) this semester. We appreciate your honest and thoughtful responses to these questions.

1. Please select the class that you are enrolled in that meets in SB 015:

GEOG-G237, MW, 9:30–10:45 a.m.
GEOG-G110, MWF, 1:25–2:15 p.m.
ANTH-P240, W, 5:45–8:45 p.m.
ANTH-E101, TR, 4:00–5:15 p.m.
GEOG-G208, TR, 9:30–10:45 a.m.
SOC-S201, TR, 11:15 AM–12:30 p.m.
SOC-S346, MW, 11:15 AM–12:30 p.m.
COLL-C105, MW, 2:30–3:45 p.m.
SPH-H351, M, 4:40–7:10 p.m.
SPH-B150, TR, 2:30–3:45 p.m.
SPH-H220, TR, 1:00–2:15 p.m.

2. What types of learning activities worked best in this classroom?
3. What types of learning activities worked least well in this classroom?
4. Please rate the extent to which the following technology was used in the classroom.

	Used every class meeting	Occasionally used	Rarely used	Never used
Video wall for display of student work	Video wall for display of student work used every class meeting	Video wall for display of student work occasionally used	Video wall for display of student work rarely used	Video wall for display of student work never used

	Used every class meeting	Occasionally used	Rarely used	Never used
Video wall for display of lecture material	Video wall for display of lecture material used every class meeting	Video wall for display of lecture material occasionally used	Video wall for display of lecture material rarely used	Video wall for display of lecture material never used
Computer and monitor at student tables for group work	Computer and monitor at student tables for group work used every class meeting	Computer and monitor at student tables for group work occasionally used	Computer and monitor at student tables for group work rarely used	Computer and monitor at student tables for group work never used
Push to talk microphones on student tables for whole class discussion	Push to talk microphones on student tables for whole class discussion used every class meeting	Push to talk microphones on student tables for whole class discussion occasionally used	Push to talk microphones on student tables for whole class discussion rarely used	Push to talk microphones on student tables for whole class discussion never used

5. To what extent did group activities help your learning in the classroom?

A great deal
Somewhat
Not at all

This question is not applicable because we did not do group activities during class.

6. To what extent did the display of student work on the video wall help your learning?

A great deal
Somewhat
Not at all

This question is not applicable because student work was not displayed on the video wall.

7. How do you feel that the room helped or hindered your learning?

8. Please indicate which of the following is appealing to you about this classroom. (Select all that apply.)

Multiple images displayed on video wall simultaneously
Technology on the student tables
Tables that support group work
Comfortable chairs
Natural lighting
Spaciousness of the room
Attractiveness of the classroom
Other (please specify)

9. Additional comments.

Appendix E: Fall 2015 faculty survey

Thank you for agreeing to participate in our study. We are trying to learn more about how instructors use the various technologies in the CLS. Your responses will help us improve training for this room and determine what kinds of technologies should be considered for future room designs. Please base your responses on your most recent teaching experience in the CLS.

Video wall

Please indicate how often you use the video wall for the following purposes:

1. Displaying learning/lecture materials

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
One large view	○	○	○	○
Quad view	○	○	○	○
16 panel gallery view	○	○	○	○

2. Displaying or comparing student work while the class is engaging in class-wide discussion

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
One large view	○	○	○	○
Quad view	○	○	○	○
16 panel gallery view	○	○	○	○

3. Monitoring student group work while students are engaging in group discussion

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
One large view	○	○	○	○
Quad view	○	○	○	○
16 panel gallery view	○	○	○	○

4. Displaying a combination of instructor materials and student materials at the same time

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
One large view (one by one)	○	○	○	○
Quad view	○	○	○	○
16 panel gallery view	○	○	○	○

5. How effective do you think the Video Wall is for comparing student work for class-wide discussion?,

- ○ Not used for the purpose
- ○ Very effective
- ○ Somewhat effective
- ○ Somewhat ineffective
- ○ Very ineffective

6. Please explain the reason for your answer above. If not used, please explain why you did not use if for comparing student work for class-wide discussion.

7. How effective do you think the Video Wall is for monitoring student group work during group discussion?

- ○ Not used for the purpose
- ○ Very effective
- ○ Somewhat effective
- ○ Somewhat ineffective
- ○ Very ineffective

8. Please explain the reason for your answer above. If not used, please explain why you did not use it for monitoring student group work during group discussion?

9. Please share what you think is your most useful or unique use of the video wall.

Other technologies in SB015

10. How often do you push learning/lecture materials to the monitors at all student tables for the following activities?

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
For lecturing	○	○	○	○
For group discussion	○	○	○	○
For class-wide discussion	○	○	○	○

11. How often do you push student work to the monitors at all student tables for the following activities?

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
For lecturing	○	○	○	○
For group discussion	○	○	○	○
For class-wide discussion	○	○	○	○

12. How often do you use the following technologies in SB015?

	Used every class meeting	Once every few class periods	A few times during the semester	Never used
Document cameras at student tables	○	○	○	○
Microphones at student tables	○	○	○	○
Portable white boards at student tables	○	○	○	○
Speakers at student tables	○	○	○	○
Instructor's wireless microphone	○	○	○	○

Appendix F: Selected segments for inter-coder reliability check

Source	Data	Category
FI	"…the fact that they have the chance to work in class to bring things together has mitigated the tension that I felt in other courses, where I've had to say: okay, you're going to have to do some of this outside of class. Because they don't have to schedule, find a common time to do some of the integration because I provide significant opportunities in class for that to happen around the tables. And I think it also means that it's harder for people to shirk. Unless they don't come to class, they're going to be sitting at the tables and they have to be working."	PS
	"I needed a classroom environment that allowed for the teams to function as a unit interacting with other teams"	PS
	These tables seem to be conducive for people to really work together	PS
	There is no spot where everyone can see you (the instructor) well because of sightline issues (in the context of discussing doing a lecture)	PS
	It is difficult to spot students raising hands during lecture even when using only the lower level	PS
	"..the ability to get a small group of students clustered around a single station where they can collaboratively talk and work through some of the technology issues and think about the principles—both in terms of, like, problem solving on the technical side, but also thinking about the conceptual ideas behind what we're doing in class—works really well for what I'm trying to do."	PST
	After small group activities it is hard to transition away from the technology and capture students' attention because of how the room is set up, with the monitors in the way to the front of the room.	PST
	Discussion is disembodied because students can't see the person talking, although they can hear it through using the mics	PST
	Because of stationery instructor's control panel and desktop in a large space where I move around, it is difficult or cumbersome to control technology	PST
	I don't lecture much but I do need to frame things for people."	PT
	Technology sometime distracts students from face-to-face interaction with each other to exchange ideas, experiences, and perceptions. I asked them to turn off thier monitors off for those times	PT
SFG	"You are like all in your own little group and you just do things as a group, and when your group is done then you leave."	P
	all the TVs have his PowerPoint up and it is really distracting. Like, I'm back there, so I see eight or nine screens that I could look at."	PST
	a. "sometimes she'll have us create a document with pictures or something like that, and then sometimes she'll post them all on there so we can see what's on all the monitors, which is kind of cool."	PT
	She (the instructor) used Google Doc for group work and displayed it on the monitors.	PT
	I prefer watching presentation on the student monitor to on the video wall. I'd say it's definitely more vivid on the monitors themselves.	PT
	"We haven't done it a lot, but we've done it once where she was like, "Do three pictures you think of when you think of complimentary alternative medicine," or something like that, so that everyone would find three pictures and then you'd put it up. And it was cool to see the similarities between groups,"	PT
	It took a while to get used to the push-to-talk microphone when talking to the class	PT
	(The large spaces makes the student feel) "not confined, comfortable, and relaxed"	S
	Being far away in the corner of the room make them feel disconnected and distracted	S
	Abundant natural light helps students to stay alert and makes classes more enjoyable	S

Note FI faculty interviews, *SFG* student focus group

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