Cabot Science Library:
Creating Transformative Learning Environments in Library Spaces

Joanna Huang
Harvard University

Anu Vedantham
Harvard University

ABSTRACT
Cabot Science Library has transformed from a traditional collections-based science library into an innovative hub for collaborative learning support. This chapter examines how a well-designed space and technology promotes effective learning and documents how Cabot functions as an smart learning environment. The interplay between a physical and digital environment at Cabot Science Library emphasizes learner mobility and engagement, collaboration and discovery, enabling knowledge creation and sharing.

Keywords: media studios, instruction room, discovery bar, flexible, Harvard, learner mobility, engagement, peer collaboration, resource sharing, digital production, wireless connectivity, knowledge creation

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Introduction

It's almost midnight on a warm summer night in August 2017. The incoming undergraduates to Harvard University, close to 1700 strong, are finishing up their Opening Days orientation events and preparing for the first day of classes. Over 450 students gather in the Cabot Science Library for Game Night. A rambunctious trivia competition is taking place at the Discovery Bar, with the live leaderboard displays on a large projection screen. About 120 students cluster in small groups, staring at the screen of a single smartphone. Each group includes four or five students who are new to each other and new to campus. They confer on a humorous name for their team phone. As a question pops up on the big screen, they whisper and choose a response on the team phone. As the timer clicks, they wait eagerly to see which team won the round. Some questions test knowledge of Harvard history. Some questions explore popular culture, news, and movies. Others tackle chemistry and mathematics. The energy in the room is contagious. Each round lasts only a few seconds and then a big cheer starts up as one team takes the lead. There will be a half-hour to relax with snacks before the next round starts.

In a departure from past practice, current undergraduate students have determined the structure and content of this library event. A sophomore created the trivia questions in an online app called Kahoots. Library administrators arranged for after-hours staffing to host this large event with music, cookies, and games until one in the morning.

Changes to learning spaces affect perceptions and usage of libraries as evidenced by the Game Night event. Library renovations brought in attributes of smart learning environments (SLEs) to emphasize mobility, engagement, knowledge sharing, media creation, collaboration and discovery. Consequently, the number of library visitors increased dramatically, tripling over pre-renovation numbers for some months of the year.

Overview

Although there is considerable debate surrounding the definition of the term SLE (Singh and Hassan, 2017, p. 9), researchers focus on adaptability to learner needs, and flexibility to promote effective learning. The Cabot Science Library provides learning spaces and technology infrastructure that redefine expectations of libraries. As Bennett (2011) argues, informal learning spaces complement the learning impact of classrooms and labs. These open spaces invite creativity, allow for exploration and play, and increase student autonomy.

The smart learning framework articulated by Zhu, Yu, and Riezebos (2016) identifies several elements of a space that make it an SLE. For example, students can "learn flexibly and working collaboratively in smart learning environments, and thus could foster the development of personal and collective intelligence of learners" (Zhu, Yu, and Riezebos, 2016, p. 15) as a result

of the customization of learning support and services. Gros (2016) reminds us that physical location and built-in capabilities play an increasingly important role in educational settings. As educators implement blended learning practices that combine virtual and in-person interaction, distinctions between the two modes increasingly blur. Students use phones to connect synchronously in class. Students stand next to peers while interacting with others who are geographically distant. Conversations in-person and online can overlap in real-time and can be represented on physical displays in creative ways. Library spaces that recognize evolving communication patterns support pedagogical experimentation by faculty.

Singh and Hassan (2017) describe how instructors use technologies familiar to many university faculty and students--for example, learning management systems--to help students develop metacognition. Self-graded quizzes with explanations help instructors embed subject knowledge within the constraints of a learning management system. For in-person collaboration, a trivia contest can function similarly.

The Cabot Science Library renovation reflects trends in library design to shift away from print collection storage towards collaborative learning support. This chapter examines how a well-designed and technologically enhanced space promotes effective learning. After describing the campus context, the space, and pedagogical background, we detail four use cases and describe changes in user experiences post-renovation.

Campus Context

Harvard is a large, decentralized and residential university, with an undergraduate body of close to 7,000 students and extensive infrastructure for science research and teaching. Student interest in science and engineering has grown rapidly in recent years, and faculty hiring has increased in response. Cabot occupies a section of three floors of the Science Center, a large nine-story brutalist building designed by Josep Lluis Sert in the 1970s. The 2017 renovation of the Godfrey Lowell Cabot Science Library (part of the Pritzker Commons in the historic Science Center) conducted by Mack Scogin Merrill Elam Architects of Atlanta, Georgia has transformed a fairly traditional library space.

Science teaching on campus is increasingly focused on active learning, small group projects, online simulations, multimedia productions and student presentations. Science research has also changed substantially, moving away from print materials and towards sophisticated use of datasets, custom software, and multimedia visualizations. These practical and cultural shifts informed the redesign of Cabot.

Space Description

The Cabot Science Library is located just near the main entrance of the Science Center. The renovation focused on removing visual clutter. Several walls have been removed completely

and others replaced by glass, giving clear lines of sight across and through the library space. The renovated space begins with a cafe with a fish-shaped table and a curving Discovery Bar behind a glass wall visually connecting the library with the main thoroughfare, a large wide ramp that several hundred people traverse each day.

The Discovery Bar, shown in Figure 1, is the most visible space in the library. It includes two projectors and large screens, one that faces inward to the library and the other on the flip side which is visible from the main ramp. This double display functions as a teaser, attracting passersby into the library when a presenter is speaking at the Discovery Bar.

The Discovery Bar leads into a flexible, open area with “puzzle tables” (so termed because their irregular shapes can be combined in a variety of configurations) that extends into an outdoor courtyard. The main floor also includes a video-conferencing room and three diner-style study booths.

Downstairs there are seven group-study rooms, three individual-study chat booths, five pods (green fiberglass constructions for individual or pair study), and an active learning Instruction Room.

The Instruction Room, shown in Figure 2, supports active learning and flipped classroom pedagogy. A touch-screen interface allows a variety of group arrangements. This 24-seat instructional space includes three whiteboards, three projectors and screens, and an overhead camera. The room has three doors and a retractable glass wall that opens out into the rest of the floor. All of the furniture is on wheels and can be stacked away in minutes. Three ceiling-mounted cameras provide the potential project into the room and broadcast activities to online platforms such as Zoom and Skype.

There are two multimedia recording studios, Media Studio A and Media Studio B, where patrons can reserve time to record and work on their multimedia projects individually or with groups on class projects. In the smaller of the two studios, Media Studio A, shown in Figure 3, there are two cameras providing different options for recording; one rearview and one overhead camera, with green screen and live render capabilities. In Media Studio B, there is an automatically adjustable rear-view camera and is optimal for recording split screen content. Both studios recording technology are controlled by a Crestron panel.

The space includes 12 movable display carts (large television monitors mounted on wheels) that can be connected to laptops and phones using HDMI wires or AirMedia wireless projection. The annotated floor plans in Figures 4 and 5 highlight the functional areas referenced above. Throughout the space are whimsical and creative furniture pieces, including colorful couch sections connected with Velcro (shown in Figure 6), chairs with cow-patterned fabric, chairs with foldable corners that resemble rabbit ears, and spinning chairs that look like tops. The furniture helps develop the sense of playfulness that led to Cabot’s recognition in the Library Journal Year of Architecture 2017 (Fox, 2017).

Background

The design of Cabot's learning spaces builds on the theory of constructivism, which holds that learners actively create and construct new information based on existing knowledge and interaction with peers and the environment. Almost every part of the new space can be moved or reconfigured easily. Boud (2010) poses a framework with four key areas: engaging learners, acknowledging the learning context, challenging learners, and providing practice (p. 240). At Cabot, users are encouraged to be generative, creative, proactive, and reflective.

According to Illich (1971), "most learning is not the result of instruction [but] rather the result of unhampered participation in a meaningful setting." (p. 38) This suggests that learning is not simply constructed in conjunction with previous knowledge, but rather co-constructed with others. This theory of learning has an essential social element to it (Papert, 1980), and builds on the concept of a zone of proximal development (Vygotsky, 1980), which suggests that learners benefit from a variety of levels and sources of guidance and collaboration. Cultivating connections between learners, as Cabot is designed to do, helps support positive interactions.

Monahan (2002) used the term "built pedagogy" to refer to "architectural embodiments of educational philosophies" (p. 5). The Joint Information Systems Committee (JISC) explains that "a learning space should be able to motivate learners and promote learning as an activity, support collaborative as well as formal practice, provide personalized and inclusive environments, and be flexible in the changing needs" (JISC, 2006, p. 30). Space changes how we think, learn, practice, and work. Anthony (1996) reminds us that the 'active' in active learning comes in many forms, writing that "students need to be cognitively, metacognitively, and affectively active in the learning process" (p. 366). The Cabot renovation was designed to support a range of student behaviors. The space is casual and friendly to noise, food, and sleep--promoting student behaviors that are casual and unrestricted. The group study rooms are outfitted with dry erase markers so that learners can make use of the walls for designing and brainstorming. The glass walls are often found covered in doodles, equations, and visualizations. The Discovery Bar and Instruction Room are well positioned for learners to quickly share what they have learned through techniques such as a gallery walk or quick presentations.

The JISC also argues that "technologies that are as far as possible mobile and wireless will support a wider variety of pedagogical approaches, and make those spaces more easily re-purposed" (2006, p. 30). Cabot's technology includes AirMedia, a user-friendly wireless presentation system, traditional projectors, mobile display screens, cameras, and microphones. With technology built-in and available, instructors and students have more flexibility in using it without prior reservation. Groups can split up and connect their laptops to the mobile display monitors, or one of the many projectors. The ease of use of the technology setup helps presenters to take risks with new pedagogical techniques.

Smart Learning Space Properties

A smart learning space supports learner mobility and engagement, enabling knowledge creation and sharing. Cabot serves college students who gather to study, collaborate, socialize, and work on their homework assignments. Cabot's spaces transform easily from presentation to collaboration mode, allowing easy transfer of control within a group of students. The variety of spaces also helps address the needs of different types of learners. The three single-person study booths for example are a great fit for the individual who prefers to study alone, while the group study rooms and movable couches work well for more social students.

Personalized learning has been described as "learning that is tailored to the preferences and interests of various learners, as well as instruction that is paced to a student's unique needs, personal interests, and innate curiosity" (Bray & McClaskey, 2012). Personalized learning emphasizes the learner's role in the creation and management of their own learning process. For example, at Cabot the instructor can easily move around the classroom (rearranging furniture and display carts as needed) to help students who need a little extra guidance without disrupting the rest of the class. Students can look up information through wireless access and collaborate during class if appropriate.

Learner Mobility and High Engagement

SLE spaces are dynamic and reconfigurable to meet specific learners' needs.

1. *Flexible Learner Interaction*

A flexible environment enables learner mobility. As learners interact multi-directionally, it is important to have "spaces capable of quick reconfiguration to support different kinds of activity such that a group of learners should be able to move from listening to one speaker (traditional lecture or demonstration) to working in groups (team or project-based activities--to working independently (reading, writing)" (Chism, 2006). With minimal training, users can quickly transform the space, allowing the presenter to switch pedagogical techniques in the middle of a presentation. The mobile carts are equipped with AirMedia and HDMI connections, and the flexibility of placement enables learners to move quickly between group and individual activities. Panitz (1999) describes a variety of group-work arrangements that can be customized to a particular professor's teaching preferences.

2. *Wireless device connectivity*

The library's wireless network supports display from any phone or laptop to any screen using AirMedia wireless projection. The display screens and carts allow groups to quickly gather in person to access and share online resources or participate in multi-player online games. Enabling library users to bring their own portable device and easily display their screen for

collaborative learning and sharing enables high engagement and adaptive interactions, two attributes of SLEs.

3. *Adaptable space design and configuration*

The renovation emphasizes the ability to clear away barriers while also separating spaces quickly by using furniture and screens as dividers. As İmamoğlu and Gürel (2016) document, the ability to demarcate boundaries clearly can improve student satisfaction with an open library space. Adaptation of the space to meet the custom needs of the learners in the moment demonstrates the responsiveness of the space design because it refers to "the adjustability of a space to the practices of individuals, such as meeting the special sensory and/or mobility needs of students. Movable furniture and walls, or re-configurable buildings, rooms, and passageways all represent this type of physical flexibility" (Monahan, 2002, p. 1). The Instruction Room in particular can be rapidly reassembled and has a retractable glass door that opens one wall in its entirety. The Puzzle Tables are all on wheels and can be rearranged quickly (Puzzle Tables, 2017). The display carts stationed around both floors of the library can echo the content of the Discovery Bar projectors through AirMedia for a wider audience to view. Flexible spaces help individuals personalize their learning experiences.

Knowledge Sharing and Creation

Cabot spaces emphasize the learner-centric concept that anyone can share and create knowledge.

1. *Real time resource sharing*

Learners can share learning materials and resources in real time throughout Cabot. Bennett (2007) observes that "physical space is needed for the *performance aspect* of teaching and learning" (p. 16, emphasis added). The Discovery Bar (see Figure 4) is a space for public talks that take advantage of the glass walls overlooking the main ramp of the Science Center. Content is visible live to several hundred people each hour as they walk in and out of the large lecture halls adjacent to the library. Cabot makes it easy for any individual to walk up and present at the Discovery Bar, and to gather an audience over time as the presentation unfolds. In addition, anyone can use the group study room monitors and the mobile monitor carts located throughout the space to access ubiquitous resources and share their laptop screens to collaborate with peers.

2. *Digital production and creative expression*

Digital production becomes a means for creative expression and demonstration of learning, and can include making paper circuits, podcasts, videos and posters. Afterwards, students can also share their products to their peers and community. Many spaces throughout Cabot promote

this creative production. The media studios in particular provide hands-on experience in creating multimedia projects, which can be shared later at the Discovery Bar.

Collaborative Learning and Discovery

Research shows that educational experiences that are active, social, contextual, engaging, and self-managed lead to deeper learning. (Chandra, 2015). An SLE fosters collaboration and supports flexible grouping and peer-learning in which learners learn from each other, discover, and co-create knowledge together. Cabot spaces support participation and collaboration.

1. *Peer and social collaboration*

Socially-aware peer-to-peer learning is facilitated by the available technology and physical design of the space. Bringing student research into the library is central to student-driven learning environments. This type of peer-to-peer interaction creates an environment of scholarly collaboration, discovery, and learning. Participants are given a platform to exchange ideas and knowledge about the research at hand. The audience has the opportunity to ask questions and also to engage with one another through inquiry and immersion into the multi-directional interactive learning experience. Cabot spaces are designed to facilitate a number of dynamic scenarios, from single- or multi-presenter events with a seated audience to small group interactions. An individual can change roles easily, moving from audience member to presenter to small-group participant.

2. *Open Participation*

Cabot supports a variety of ways for groups to collaborate. The technology infrastructure is set up so that anyone can connect easily in order to participate. The media studios are bookable by all students and faculty, and are geared towards project creation in a team-based structure, but can also be operated by a single individual. The process of multimedia creation in the media studios often involves task distribution with the production process--hardware-related activity such as camera placement, monitoring audio levels or software manipulation. Group members choose their roles and tasks. The interaction during a video shoot or podcast production can provide a platform for an exchange of ideas between group members in addition to improving acquisition of media production skills.

Four Case Studies

The following cases document how Cabot functions as an SLE.

Undergraduate Science Research Spotlight – A Discovery Bar example

“Bong!”; the gong goes off to indicate it’s time to move on to the next student research presentation. A crowd of peers, mentors, and advisors claps as each student presents the

research they have done in the past year. In fall 2017, Harvard undergraduates concentrating in science, mathematics, and engineering presented their summer research results at the library's first semi-annual Undergraduate Science Research Spotlight. Ten undergraduates spoke for three minutes each at the Discovery Bar and then answered questions next to their research posters in the Puzzle Table area. These "lightning talks" attracted an audience that included faculty and staff from across campus, as well as the students' friends and classmates. This event recognizes the value of peer learning as a learning strategy (Grabinger & Dunlap, 1995).

At the spotlight event, the audience demonstrated high engagement, one of the SLE attributes. The Discovery Bar signaled flexibility and learner mobility where participants would move from sitting and listening, to standing and presenting, to walking around and interacting with peers and mentors. They could switch quickly from an expert presenting research to a learner discovering something new.

Game Design by Librarians – An Instruction Room example

About 20 librarians gather in the Instruction Room, shown in Figure 5, to discuss how to create games to enliven library presentations. The tables are set in groups of five. The facilitator opens with a few demonstrations on the three projector screens that display on two of the room's four walls. With the demonstrations over, the screens retract into the ceiling so that groups can use the glass whiteboards behind them. Each group designs the rules for a game. Participants draw on the clear glass walls that separate the room from the rest of the floor in addition to the glass whiteboards. Some groups leave the classroom to find a group study room nearby. By the end of the hour, the walls around the classroom are covered in writing and diagrams. The groups then review each other's work in a gallery-walk format.

The Instruction Room is highly adaptable. The tables, chairs, and one wall can be moved out. In this game design activity, the participants collaborate actively and document ideas on the walls and on mobile devices.

A Student Podcast Channel – A Media Studio example

During the fall of 2017, two Harvard sophomores set out to discover how their peers spend their 4 years at Harvard. Using the Cabot Media Studios, they decided to capture these stories through a podcast channel devoted to graduating seniors' reflections on their experiences at Harvard (Buckley, 2017). The student hosts of the 8-episode podcast series named their project "Two Million Minutes," a rough estimate of how much time an undergraduate spends at Harvard before graduation.

The Media Studios support the creation of user-driven multimedia projects at Harvard as a self-service space equipped with professional-grade audio and video equipment. From setting the stage, choosing at what camera angle to film, and what audio to record, users can make decisions about their projects. The studios can accommodate individuals and groups. The "Two

Million Minutes" podcast acts as evidence of a creative expression outlet by the student hosts who have collaborated with each other and guest speakers.

Other media studio projects include single-speaker videos, live demonstration of a project, animation, group interview, and podcasts. Users are encouraged to take control of the entire process through the self-service media studios, a technology lending program, and computers equipped with media-editing software.

Foot Traffic Digital Visualization – A library-wide example

The students who walked through the entrance of Cabot last May never suspected that their footsteps were registering on a weight-sensitive doormat installed at the turnstiles that fed real-time traffic data to a display on the lower level. An undergraduate student-created art exhibit for a course on digital media design provided a visualization of Cabot's door count, which controlled the colors of flood lights mounted on the lower level. Conceptually, a patron on the lower level can experience the activity of patrons entering the library from upstairs via the lighting effects. Downstairs, students played with the colored light display, creating shadow puppets over a cardboard house. As the traffic patterns changed on the first floor, the color palette on the lower level responded in real time. Video recordings of students performing on the lower level captured this live demonstration. The cardboard house itself attracted a good bit of curiosity.

Throughout the library space, there is a sense of openness and flexibility. By hosting temporary class project installations such as this one, library staff support technical experimentation as well as a sense of play. This particular installation addressed library priorities of integrating into the academic curricula for the sciences. The installation shifted control over the library environment into the hands of the students. Multi-sensory platforms, like the one described earlier, allow for user manipulation to modify the learning environment.

User Feedback

Cabot opened after renovation in April 2017, and the Harvard Library User Research Center conducted a series of surveys and observations to measure impact. Gate counts post-renovation are substantially higher across the board, with a dramatic increase from under 23,000 in earlier years to over 61,000 in October 2017. The top three reasons selected by students for why they chose to study in Cabot rather in other spaces around campus were:

1. Convenient location
2. Social aspect / collaboration
3. Like the modern atmosphere / space

Students also provided comments and suggestions including:

- “I wanted to meet in a location that we could talk candidly, and which was conveniently located for my group.”
- “It is central, social, and aesthetically pleasing.”
- “Quiet enough to do work but loud enough where it isn’t irritating.”
- “You can talk and there is food.”
- “Not much to change! Cabot is great!”
- “I would like the upstairs area to have more vibrant furniture.”
- “Make a completely silent area but where you can eat.”

Overall, the renovation has proved very popular with students (FAS Communications, 2017 and 2017-2) and increased use has also generated increased demand for support and expansion of similar capabilities to library spaces elsewhere on campus.

Future Improvements

As we assess the first year of the Cabot Science Library, we note the dramatic increase in foot traffic and demand for events to take place in the renovated spaces. We note increasing interest in adding a few quiet study locations to complement the collaborative spaces.

We hope to add functionality that is location-aware and interactive. First, one possible improvement would build on the SLE concept of moving from user-pull of information, to a system-push of information. Instead of the user initiating a search for information on a topic, the library infrastructure would initiate suggestions based on the topics students are addressing and about which they are accessing information, the location of expert staff, as well as location of nearby print and electronic materials. For example, students could opt-in to receive heads-up messages when an expert on a particular topic is near them in the library.

Context-aware is defined by Zhu et al. (2016) as “exploring different activity scenarios and information” (p.3). Many different activities can occur within a single space, and modern libraries are a prime example of a space that serves many different needs. It becomes important for sensors to determine if someone is working alone, or with only one other person, or in a group, and if the interaction mode is quiet or actively collaborative. For example, a user may be working independently, and would best be served by information pushed to their phone or computer based on their proximity to materials on the same topic on nearby shelves, or with the same subject tagging (subject headings) as their work. Alternately, a student may be working as part of a group, and need to access information about the proximity to resources for sharing online content, like a large screen monitor, where the whole group can see without having to crowd around a laptop.

The Discovery Bar could be enhanced through the technologies related to the Internet of Things, where physical objects connect into a digital network and can be transformed by commands. One could imagine ways for the space itself to suggest to users ideas on how to

rearrange the furniture. Meshing location-aware technologies that can sense where a device is and offer information related to that location would help students make the most of the library space without requiring training from library staff. Students who have a question during another student presentation could receive suggestions of recommended library resources in the moment. When a student approached the poster session area, such technology could surface relevant materials to orient users before they engage with the student presenter.

In the Instruction Room, technology that reveals when a participant needs additional attention would improve active learning instruction since the instructor could walk around more efficiently, and reduce the barriers for the student to ask for help. Existing technologies for back-channel conversations during class could be integrated into the Instruction Room so that the instructor could adjust focus during class.

User experience in the media studios could be improved by adding integration with Harvard's learning management system (LMS), Canvas, to provide a platform for personal and academic portfolios. If the software in the studios could connect directly to the LMS, students could store, edit, and share their multimedia projects more easily within a course context. Multimedia projects tied to a particular class assignment could include rubrics and other guiding material for library and academic support staff when students have questions at the studios.

Conclusion

As Hunter (2006) notes, the role of libraries in providing learning spaces on campus has grown significantly. Students and faculty expect library spaces to include SLEs that support a variety of learning activities. Altering the learning environment, especially the physical space and technology, can change how people learn. A well-designed space with strong technology supports active learning and helps interchange the roles of instructor and learners. We have described the SLE capabilities of Cabot with the cases above.

The renovation of Cabot Science Library had at its heart design principles to support both informal and formal learning. A user research study indicated that individual study, group collaboration, and leisure activities all occur in the library at different times of the day and prevalence of one use or another varied over the course of the academic year. For instance, student use of Cabot during reading week or finals is more traditional, with all seating taken by students working silently over laptops and notebooks. Students often develop patterns of use where they regularly return to the same spot. The use of whimsical furniture encourages users to strike a balance between work and play. Students routinely rearrange the furniture.

Compared to more traditional library spaces, Cabot offers versatility. The open plan and furniture on wheels enables events to be hosted in a way not possible prior to renovation. The central location also increases visibility of events at Cabot. As a result, a wide array of community partners now recognize Cabot as a desired location for events.

We recognize that the Cabot renovation provides an unusual opportunity to design a new space around principles of learning design. There are smaller interventions that can be implemented in educational spaces without a full renovation. As mentioned earlier, a hallmark of SLEs is the adaptive uses and appropriate feedback to activities. Adapting spaces and furniture to embrace flexibility and multiple uses, along with judicious inclusion of technology, can make a traditional space closer to being an SLE. The decision to move book storage out of libraries and repurpose space for student-centered support is increasingly common across the country. Rather than just putting in comfortable seating and study tables, designers can enhance the space with avenues for group engagement, such as mobile whiteboards, detachable furniture and large movable display screens. Creating spaces that emulate the feedback and interactions in SLEs opens the door for automated interactions. Moving forward, efforts to couple smart technologies with common student behaviors will further library support of campus learning initiatives.

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Figures

Figure 1 Discovery Bar

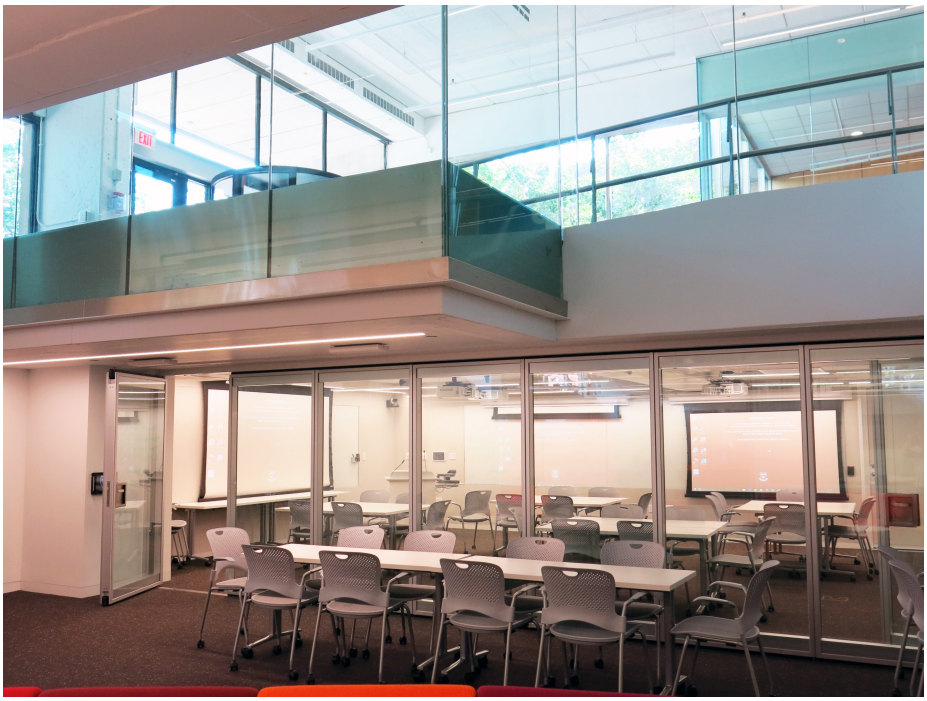
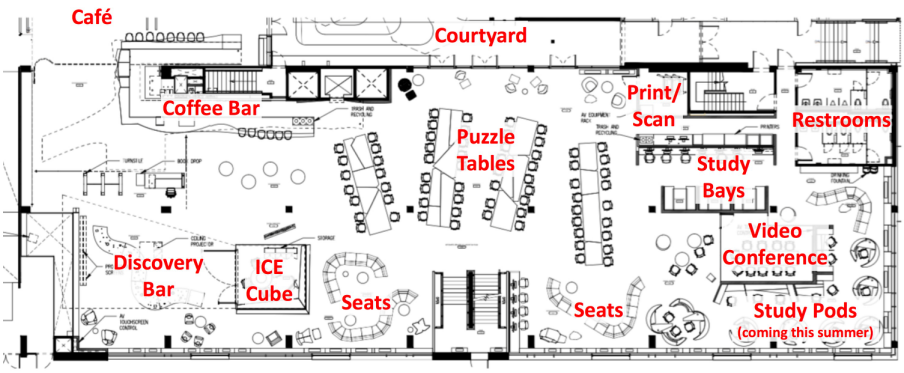


Figure 2 Instruction Room

Figure 3 Media Studio A



Cabot's first floor has the Discovery Bar and connects with the café and courtyard

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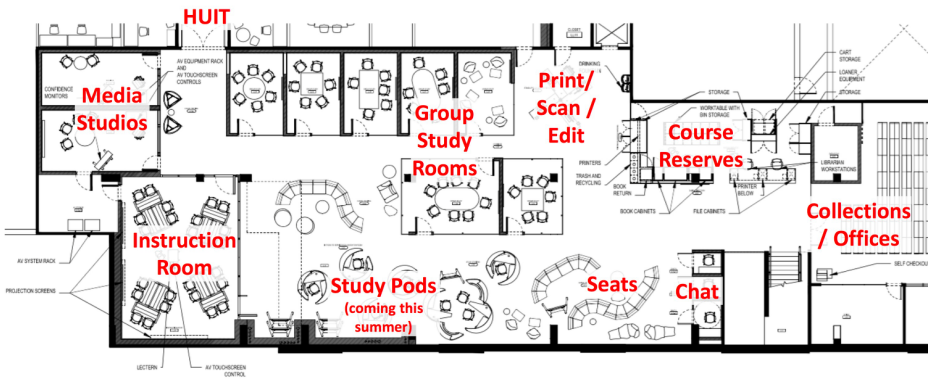
Figure 4 Main Level Floor Plan



Cabot's lower level supports new media, group study, course reserves and collections.

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Figure 5 Lower Level Floor Plan

Figure 6 Colorful couches