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Adopting Active Learning Classroom (ALC) Technology and Overcoming Barriers: A Faculty Development Intervention Model for Technology-Enhanced Learning Spaces

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Adopting Active Learning Classroom (ALC) Technology and Overcoming Barriers: A Faculty Development Intervention Model for Technology-Enhanced Learning Spaces

A Dissertation Presented

by

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DEDICATION

To all educators, always know that your efforts transform lives in so many powerful ways, beyond what you can ever know. Thank you for your dedication to growing minds, challenging questions, and constant feedback – it makes a big difference!

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ABSTRACT

ADOPTING ACTIVE LEARNING CLASSROOM (ALC) TECHNOLOGY AND OVERCOMING BARRIERS: A FACULTY DEVELOPMENT INTERVENTION MODEL FOR TECHNOLOGY-ENHANCED LEARNING SPACES

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The goal of this study was to understand how instructors use technology, and what challenges they face, but also to increase the participants' understanding of Active Learning Classroom (ALCs) technologies as it applies to their teaching by applying action research methodologies. This study also seeks to lay a foundation for additional research on ALCs, education technology, and the needs of instructors in terms of faculty development in technology.

This study investigates a group of 13 faculty members in multiple disciplines teaching in ALCs. Thus far, research on the impact of technology-enriched learning environments like Active Learning Classrooms has typically centered around student learning (Beichner et al., 2007; Frazee, Hughes, & Frazee, 2014; Morrone, Ouimet,

Siering, & Arthur, 2014). Less attention has been paid to the faculty development needed for instructors to properly take advantage of these environments

The research study addresses three questions: First, how and, for what purposes, do faculty use technology in the ALC? Second, what technology adoption factors and barriers were experienced by instructors in an Active Learning Classroom? Third, using Kolb's experiential learning theory (1984, 2014), how does a semester-long faculty development intervention program impact instructors' adoption of Active Learning Classroom technologies?

Results indicated that the most frequently used technologies were those that were familiar from traditional (technology-equipped) lecture spaces that faculty had used. Faculty were most comfortable with content delivery tools such as instructor laptops connected to the LCD TVs, the instructor podium, and whiteboards. Additionally, technology adoption factors and barriers to adoption were identified, including time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. Through action research, the newest Active Learning Classroom instructors received the most hands-on training on the classroom hardware during consultations, and the exposure to classroom technologies and troubleshooting tips via an experiential learning framework allowed them to better understand the podium interface, document camera and wall-buttons while having an opportunity to reflect on their teaching.

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INTRODUCTION

"The importance of faculty development in technology (FDT) in the twenty-first century is not disputed. The need for FDT programs that provide faculty with training is an on-going process which requires continual implementation of current best practices" Collins (2014, p. iii).

This dissertation includes six chapters. The first chapter is an introduction to this action research study on instructors' ALC classroom technology use. The second chapter reviews the literature on technology-enhanced classrooms referred to as Active Learning Classrooms (ALCs) and the associated challenges instructors experience with technology in these spaces. Chapter three describes the theoretical framework, which is based on experiential learning and is studied through action research methodology. The fourth chapter details the methods, data collection process, analysis, and limitations of the study. Chapter five provides results for the three research questions. Chapter six discusses the results. Further details about the study are available in the appendices at the end of this research study.

Background to the Problem

Education technology can have a profound effect on student learning. When used effectively, technology in the classroom can help students engage with course material, the instructor, and each other (Dahlstrom, Walker, Dziuban, & Morgan, 2013; Johnson, S., Estrada, & Freeman, 2015; Venkatesh, Croteau, & Rabah, 2014). Students can quickly manipulate or modify their ideas using widely available tools like laptops, tablets, mobile phones, and web-based services (Baepler, Walker, Brooks, Saichaie, & I., 2016; Bishop & Keehn, 2015; Dahlstrom et al., 2013). Technology can be used to facilitate student collaboration on meaningful and authentic learning tasks, making students' education more applicable to real-world challenges beyond the classroom (Collins & Halverson, 2009). Technology also supports online peer-review and collaboration opportunities outside the classroom (Felder & Brent, 2016), as well as allowing students to receive more immediate feedback in class using audience response systems (Caldwell, 2007; Good, 2013).

Given the well-documented benefits of education technology, higher education institutions invest significant capital in infrastructure to facilitate technology-enhanced learning. Likewise, faculty are encouraged to take advantage of these dynamic new learning environments both online and in traditional classrooms. The 2015 EDUCAUSE ECAR study, which included 17,451 respondents from 151 institutions, found that "many faculty think they could be more effective instructors if they were better skilled at integrating certain kinds of technologies into their courses" (Dahlstrom, 2015, p. 18). Students may also perceive a link between effective instruction and an instructor's ability to integrate technology. In a study of how students perceived Active Learning Classroom environments, Baepler et al. found that "technological prowess is a significant factor linked to student acceptance of the [ALCs], because survey data have indicated that many students perceive that their instructors are unskilled in implementing technology in ALCs" Baepler et al., 2016, p. 190).

Thus far, research on the impact of technology-enriched learning environments like Active Learning Classrooms has typically centered around student learning (Beichner et al., 2007; Frazee, Hughes, & Frazee, 2014; Morrone, Ouimet, Siering, & Arthur, 2014). Less attention has been paid to the faculty development needed for instructors to properly take advantage of these environments and their technology. In 2015, I developed a pilot study to investigate the barriers to technology adoption and adoption factors experienced by instructors transitioning to ALCs. I found that aside from EDUCAUSE's recent study of faculty technology use, Van Horn et al.'s (2014) study on faculty's adoption of Active Learning Classrooms, and a study conducted at Worcester Polytechnic Institute on faculty technology use in ALCs, the literature is relatively lacking in this domain. This gap in the literature may be caused in part by a lack of faculty development available to help instructors transition their pedagogy into technology-rich classrooms, as "University faculty members have been among the last educators to experience the educational thrust toward technology integration" (Nicolle, 2005, p. 36).

Statement of the Problem

While supporting technology-rich pedagogy is a vital skill set that needs to be developed in faculty, facilitating the transition into new learning environments with new classroom technology is a major challenge for universities today (Baepler et al., 2016). For example, technology requires dedication and practice to implement in the classroom, and faculty frequently report lack of time as a barrier to the adoption and effective use of classroom technology (Butler & Sellbom, 2002; Kagima & Hausafus, 2001; Lin, Huang,

& Chen, 2014; Mrabet, 2009; Nicolle, 2005). Also, instructors require both training in how to use classroom technology at a technical level, and support in applying it effectively at a pedagogical level. These resources are not always available to faculty; and, when resources are available, they tend to focus more on mastering technical skills than developing effective strategies for using technology to enhance learning. In the absence of robust faculty development opportunities, instructors frequently gravitate towards using technology tools they know and instructional strategies with which they are already familiar -- which leads to underutilized technology in technology-rich learning spaces. Finally, educational research lacks the data necessary to properly understand and implement best education technology practices for faculty teaching in ALCs.

Statement of Purpose

Given the importance of education technology for today's students, and the financial investment universities have made in recent years to construct technology-rich classrooms, researchers and educators should explore the best ways to assist instructors in using technology in their teaching.

This research study adds insights into the practitioner field of faculty development in technology by way of the action research methodology. Action research methodology seeks to accomplish two things. According to Dick (1993), it seeks to "bring about change in some community or organization or program [and] increase understanding on the part of the researcher or the client, or both and often some wider community" (p. 4).

In the case of this research study, action research methods were applied to address the technology challenges instructors experience in one of the most technology-rich learning environments in higher education today: Active Learning Classrooms (ALCs).

The goal of this study was to understand how instructors use technology, and what challenges they face, but also to increase the participants' understanding of ALC classroom technologies as it applies to their teaching. This study also seeks to lay a foundation for additional research on ALCs, education technology, and the needs of instructors in terms of faculty development in technology.

Research Site

For this study, I examined the Active Learning Classrooms (ALCs) at a large research university in the Northeast. The university recently constructed five ALC classrooms and encouraged instructors from any program or discipline to teach in these new learning environments. I selected these ALCs for this study because they were newly equipped with the latest educational technology, and their availability to different disciplines meant the classroom technology could be used to meet a variety of discipline-specific instructional strategies.

Theoretical Framework

I used the Experiential Learning Theory (Kolb, 1994, 2014) as a framework for exploring ALC classroom technology usage, adoption, and barriers to adoption. Experiential Learning provides four discrete phases: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Applying this framework allowed me to engage participants in a hands-on approach to help them address particular, discipline-specific technology challenges in their classrooms. The two-way process of engaging both the participant and the researcher allowed for a more transformative research process that benefited the research study and the participants' ALC technology skill sets as well.

Research Questions

In this study I address two primary research questions about faculty use of technology in Active Learning Classrooms:

> ***R1: How, and for what purposes, do faculty use technology in the ALC?***
>
> ***R2: What technology adoption factors and barriers were experienced by instructors in an ALC?***

While I designed this study to explore how instructors use technology in Active Learning Classrooms, it was also designed to empower instructors to use technology in meaningful ways to enhance student learning. Therefore, using Kolb's Experiential Learning Theory (1984, 2014), I also examined a third research question:

> ***R3: How does a semester-long faculty development intervention program impact instructors' adoption of ALC technologies?***

Methods

In order to examine the above research questions, I followed 13 participants through an action research data collection strategy. First, I observed participants teaching in their ALC. Second, the participants completed an online survey based on prior research in faculty development in technology. Finally, instructors participated in a semi-structured one-on-one consultation regarding their ALC technology use. In the post-phase, an additional observation, survey, and semi-structured consultation concluded the data collection activities. The data collection occurred over six discrete periods in a single semester, with each phase informing the next.

Phase 1: Observation. In the first phase of the data collection process, I observed 13 instructors in their ALC classroom within the first two-weeks of their class. Positioned behind the instructor podium, I utilized an observation protocol that focused on instructors' use of the twenty-five ALC technology equipment pieces.

Phase 2: Survey. For the second phase of the data collection process, I designed an online survey which asked instructors to describe their technology use, the importance of the 25 pieces of ALC classroom hardware, and the challenges they experienced with the classroom technology. I deployed the survey in week four of the semester. I selected an online survey method in order to easily gather data consistently from multiple participants. All 13 instructors in the study completed the survey.

Phase 3: Consultation. In the third phase of the data collection process, I conducted faculty development consultations regarding instructors' use of ALC technology. I consulted with all 13 participants regarding their own classroom technology adoption factors and barriers, while also providing technology consultation support. By conducting in-depth consultations with action research, I was able to explore technology usage and address challenges with the hardware.

Phases 4, 5, 6. The next three phases repeated the measures taken in phases 1, 2, 3, but occurred during the second half of the semester in order to re-address the challenges and barriers instructors experienced.

Data Analysis. I conducted thematic analysis (Braun & Clarke, 2006) for the entire data set using NVivo. The dataset included 13 participants with two observations, surveys, and consultation interviews each. Additionally, I analyzed quantitative data using SPSS and Microsoft Excel to report descriptive statistics. Using a combination of open codes and prescribed codes from literature on technology adoption and barriers (Ertmer, 1999), combined with experiential learning theory, I explored the data for latent patterns using my own new data analysis technique using multiple LCD displays, audio/video, transcript data, and NVivo software. This process helped to uncover themes and subthemes in qualitative data (Ryan & Bernard, 2003).

Results

Overall, the most frequently used technologies were those that were familiar to faculty and those that they had previously used. Faculty were most comfortable with their own instructor laptops connected to the LCD TVs, the instructor podium, and whiteboards. Secondly, technology adoption factors and barriers to adoption were found and importantly linked on a continuum in this study, these included time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. The most novice instructors received the most hands-on training on the classroom hardware during consultations, and this exposure to classroom technologies and troubleshooting tips allowed them to better understand the classroom technology while having an opportunity to reflect on their teaching.

Limitations

In this study, I explored the experiences of 13 participants teaching in ALC classrooms. While all participants completed each of the six instruments, the small sample size makes the results difficult to extrapolate to all college and university contexts. Also, the recruitment process yielded few instructors who were new to the learning environment. Instead, the majority of participants were veteran ALC instructors who largely showed a well-developed technology savviness regarding the classroom equipment. They may not be representative of an average instructor beginning to teach in an ALC learning environment.

Delimitations

I delimited this study to higher educational instructors teaching in ALC classrooms at a research university. I specifically focused on instructors' use of educational technology through a variety of research methods. I do not include information from students in this study, nor do I address student learning outcomes based on instructor's use of education technology in the classroom, as this was beyond the scope of the research questions. Since the aim was to examine instructors' use of technology hardware in the ALC learning environment, I did not include online platforms such as the Learning Management System and other web-based tools as part of the study.

Conclusion

Conducting research on faculty's use of new learning spaces is a vital and important topic for the fields of education technology and faculty development. The following chapters address the three research questions pertaining to ALC's technology adoption use. Beginning with the next chapter, I provide a synthesis of literature on ALCs technology adoption, barriers to adoption, and associated faculty development initiatives. In chapters three and four, I address the action research methodology and instrumentation of the semester-long study in the context of experiential learning. I cover the results in chapter 5, while chapter six provides a discussion of the results as they connect to the existing literature. I conclude the research study with chapter seven, which provides a broad conclusion of the research.

CHAPTER 2

LITERATURE REVIEW

In the previous chapter, I highlighted the need for a hands-on approach to studying faculty development in Active Learning Classrooms (ALCs). In this chapter, I will discuss key findings from the literature related to ALCs, technology adoption, barriers to adoption, the role of faculty development in addressing such barriers, and models that are available for technology integration in the classroom.

Introduction

As part of a comprehensive literature review on the topics of Active Learning Classrooms, education technology adoption factors and barriers, and faculty development, I selected articles for review based on an extensive search across several research databases, including Education Journals, ERIC, and Libraries Worldwide. I then narrowed these results to articles published within 15 years, the majority of which were peer-reviewed. Several seminal pieces outside this domain were included due to their relevance to the topic. I imported all documents into NVivo for analysis and coding. Several themes emerged from the review, including a deep incorporation of education technology in ALCs, the positive impact of ALCs upon student learning, and the need for pedagogical training of faculty to foster these benefits. Further, this review revealed a lack of differentiation between technology adoption factors and barriers, indicating that the two are likely interrelated.

Active Learning Research

The concept of the active learning classroom arose from the broader literature on active learning. Active learning provides students with opportunities to engage in non-traditional, non-lecture-based activities that, independently and collaboratively, engage them with the course material (Forsgren et al., 2014; Freeman et al., 2014b; Prince, 2004). Active learning is commonly referenced in higher education research and practice as an umbrella term to cover a variety of pedagogical strategies that instructors employ in order to engage the learner more deeply than what can be achieved using traditional lecturing (Forsgren, Christensen, & Hedemalm, 2014; Freeman et al., 2014b; Prince, 2004). These strategies range in scope, and have variously been termed “active,” “cooperative,” “collaborative,” “case-based,” and “problem-based” learning, among other terms used for non-lecture-based teaching strategies (Forsgren et al., 2014; Prince, 2004).

Although the relevance of these strategies to different disciplines varies, active learning techniques have been demonstrated as effective (Prince, 2004). For example, a meta-analysis of 225 studies in STEM classes conducted in 2014 reported that students in the active learning sections of a class improved their exam scores by an average of 6%, while those in traditional class sections were more likely to fail the exams (Freeman et al., 2014b). Active learning in a nursing course found positive results using case-based methods for teaching. By examining authentic case studies in nursing, student learning improved by making theoretical knowledge in the nursing discipline more realistic through active student engagement with theory. Students gathered knowledge and argued for their own interpretation of the cases (Forsgren et al., 2014). Regardless of the specific active learning strategy, students are more likely to perform well on tests and engage in more authentic applications of learning with active learning than can be afforded during traditional lectures.

Active Learning Classrooms Research

The Active Learning Classroom (ALC) provides the main setting for realizing active learning pedagogy. The ALC offers a space to encourage a transition in pedagogy that favors a student-centered approach to teaching, and research indicates that ALCs positively impact student learning just as active learning pedagogies do (P. M. Baepler, Walker, Brooks, Saichaie, & I., 2016; Beichner, Saul, & Allain, 2000; Ferris, Jennie, Weston, Cynthia B., Finkelstein, 2009). In particular, ALC research illustrates that the ability of classroom design (a classroom's layout and learning space configuration) to support the socialization and problem-solving aptitude of students constitutes a key factor for fostering the kind of student-centered learning essential to active learning performance and success.

Classroom Design and Socialization

Much research has been dedicated to identifying the impact of the learning environment on student learning over the past decade. Classroom design itself remains a focal point of research since layout and orientation have been correlated with student attitudes and success (Muthyala & Wei, 2013; Park & Choi, 2014).

ALCs differ greatly from their traditional counterparts in their high level of technology integration and a radically different usage of classroom space that necessitate new classroom management techniques on the part of instructors. Traditional classrooms are typically designed with fixed rows of chairs or auditorium-style seating. The instructor is usually located at the front of the room, and may or may not have sufficient space to easily move about the classroom in order to employ student-centered approaches (Beichner et al., 2000). Traditional classrooms are often equipped with limited technology hardware, such as a single projector and a small technology cabinet. In contrast, the technology in ALCs has been infused into the learning space design (Baepler et al., 2014; Beichner et al., 2000; Gebre, 2012; Gebre et al., 2014; Narum, 2013; University of Massachusetts Amherst, 2012a; Walker et al., 2011).

In a 2013 study, researchers compared two types of ALC learning spaces: one configured with rectangular student tables clustered in spokes radiating from the center of the classroom, and another with nodes where pods of students huddled in clusters using rolling desk-chair furniture (Muthyala & Wei, 2013). Students were more familiar with the node layout, which maximized mobility for students in the classroom. However, it proved difficult to share work with other students given the desk-chair combination, while the spoke layout allowed students to foster group discussion and gave them more space to spread out and problem solve, although it was difficult for all students to pivot easily to see whiteboards or student lecture notes. Student performance on exams and audience response systems showed no statistical difference between the two configurations, suggesting the ALC space and pedagogical alignment were not critical to student success (Muthyala & Wei, 2013). Similarly, researchers comparing ALC designs with traditional classrooms discovered that ALCs overcome the "golden" and "shadow" zones inherent in traditional classroom design. These physical areas in a traditional classroom are known to better support student learning, or “golden” while others that are less ideal, or “shadow” zones. Students in ALC’s did not report the same frustrations associated with golden or shadow zones. They subsequently conclude that “higher education institutions should pay more attention to the educational impact that classroom design has on students, and make investment in healthy learning spaces a priority” (Park & Choi, 2014, p. 769).

The role of student socialization has emerged as an important theme in considerations of optimal classroom design. As quoted in Weidman (2006), socialization was classically defined by Brim (1966) as “the process by which persons acquire the knowledge, skills, and dispositions that make more or less effective members of their society.” Student socialization refers to the impact of student peers on theirs socialization. Employing a mixed-method approach, Beichner found that the configuration of the classroom with round tables and whiteboard spaces was vital to supporting student socialization and positive learning impacts (Beichner et al., 2000). MIT researchers similarly found that socialization was critical to the construction of knowledge, in this case based on a study with a control and experimental group in an ALC environment (Dori & Belcher, 2005). Similarly, in a study that combined faculty and student surveys with focus groups, research conducted on ALCs by Baepler and Walker (2014) and Brooks (Brooks, 2011) showed that students in ALC environments form stronger connections with fellow students and faculty alike.

In addition to the ability of classroom configuration to foster a social connection, the attitudes of faculty and students toward teaching and engagement also have been found to be important success factors. Gebre (2014) conducted research in an ALC classroom using quantitative analysis and showed that "the extent of students' cognitive and applied engagement and social engagement is related significantly to professors' conceptions of effective teaching" (p. 84). ALCs also had a measurable effect on how students perceived their learning experiences and their engagement levels (Byers, Imms, & Hartnell-Young, 2014). Gebre uncovered four specific dimensions to student engagement in ALCs: "cognitive and applied engagement, social engagement, reflective engagement and goal clarity" (p. 84).

Several studies have measured improved student performance resulting from ALCs. In a study that used a control and experimental group, Brooks (2011) found that students taught in an ALC outperformed those in a traditional classroom. Similarly, in a multi-year study Beichner et al. (2007) divided over 16,000 students into control and experimental research groups, and found that those taught in the experimental group, which used an ALC classroom, outperformed their peers taught in traditional lecture hall spaces (Beichner et al., 2007, 2000).

Technology in ALCs

From their beginning ALCs have been associated with the integration of the latest technology as a prime characteristic. Higher education institutions continue to invest resources into both hardware and software technology (Dahlstrom & Brooks, 2014; Kyei-Blankson, Keengwe, & Blankson, 2009; Saadé, Nebebe, & Tan, 2007). As part of this trend, universities are increasingly building, or renovating, technology-rich classroom spaces with attention to student-centered or active learning environments (Beichner, Saul,

& Allain, 2000; D. C. Brooks, 2011; Harvey & Kenyon, 2013; Montiero, 2012; Walker, Brooks, & Baepler, 2011).

Technology-laden classrooms and learning spaces are known by a variety of terms in higher education. While McGill University and the University of Minnesota refer to the classrooms simply as Active Learning Classrooms, many classrooms employ the term Student Centered Active Learning Environment with Upside-Down Pedagogies (SCALE-UP) classrooms, which trace back to designs pioneered at North Carolina State University and the University of Minnesota (Beichner et al., 2007; Walker et al., 2011). MIT has Technology Enhanced Active Learning (TEAL) classrooms, while Worcester Polytechnic Institute and the University of Delaware call these spaces Problem-Based Learning classrooms. The University of Iowa refers to the classrooms as Transform, Interact, Learn, Engage (TILE). A full list of ALCs can be found online at: https://goo.gl/8iaRd0.

Most ALCs incorporate a plethora of technology hardware tools that are accessible to both the instructor and students, often for the purpose of facilitating group or team-work styled instruction (Baepler, Brooks, & Walker, 2014; Beichner et al., 2000; D. C. Brooks, 2011; Gebre, Saroyan, & Bracewell, 2014; Narum, 2013; Staros, 2013). The classrooms typically include round tables for student seating and an instructor station located in the center of the room, rather than at the front (Alwash, Grills, Hinrichs, & Wasserman, 2014; Drake & Battaglia, 2014; Foote, 2014; Gebre, 2012). This configuration is said to better democratize the classroom space and foster collaborative learning. Along these lines, ALCs often include movable chairs and whiteboards for students. Team tables are also often connected to LCD displays where students can project their computer screens to share work with the rest of the class (Baepler, Walker, Brooks, Saichaie, & I., 2016).

In traditional classrooms faculty often utilize technology for lower-order pedagogical learning activities that lend themselves to traditional teaching models, such as memorization. By contrast, each ALC is designed as a constructivist learning technology environment. Constructivist learning technology environments were first defined by Jonassen (1994) and summarized by Harasim (2011). These environments are designed to create multiple representations of content for learners, mimic the complexity of the real world, provide opportunities for knowledge construction through authentic tasks and critical reflection, and facilitate collaborative learning (Harasim, 2011; Jonassen, 1994). As constructivist learning environments, ALCs are designed to foster higher-order pedagogical activities that allow students to learn by creating and applying knowledge to new contexts (Keengwe, Kidd, & Kyei-Blankson, 2009; Lawless & Pellegrino, 2007; Reid, 2014; Selwyn, 2010).

Although many studies have investigated technology as it pertains to active learning, they often focus only on tools associated with pedagogical techniques (blending, flipping) while leaving other ALC classroom hardware unexplored (Keengwe, Georgina, & Wachira, 2010; Oliver-Hoyo, Allen, Hunt, Hutson, & Pitts, 2004).

Faculty Transition to ALCs

Regardless of the classroom environment and technology, the pedagogical shift instructors experience in ALCs presents them with many challenges. The new learning environment requires instructors to drastically shift their teaching styles while leveraging new technologies that enable active learning.

Although some studies have investigated faculty training with respect to course design for ALC instruction, many have not investigated the on-the-ground technology adoption experience in order to understand the barriers faculty encounter (Alwash et al., 2014; Frazee, Hughes, & Frazee, 2014; Morrone, Ouimet, Siering, & Arthur, 2014). As faculty transition to teaching in ALC classrooms, they must make decisions about how they will situate their instruction within ALCs equipped with a variety of technology tools. This was confirmed in a pilot study I conducted in ALCs (Wheeler, 2015). A series of complicated decisions must occur with regard to the space, pedagogy, and learning technology (D. C. Brooks, 2011; Ertmer & Ottenbreit-Leftwich, 2010; Reid, 2014; Walker et al., 2011, Wheeler, 2015).

Technology integration proves challenging even in traditional classroom spaces (Johns, Estrada, and Freeman, 2015), let alone in the ALCs, such that “the problem of integrating technology into teaching and learning processes has become a perennial one” (Okojie, Olinzock, and Okoie-Boulder, 2006, p. 30). It is clear that faculty in both traditional and ALC classrooms require support and consultation in order to effectively employ learning technologies (Dahlstrom & Brooks, 2014). However, studies have largely ignored the factors that influence faculty members’ adoption of technology, as well as barriers to such adoption, in ALCs in particular (Walker et al., 2011, Wheeler, 2015).

Michael (2007) examined barriers to active learning in traditional lecture style classrooms and found that “teachers perceive many different barriers to building an active learning environment in their classrooms" (p. 46). These included: concerns about abandoning prior teaching strategies, lack of time, covering content, student resistance to active learning pedagogies, and low teaching evaluations. Similarly, a recent study of faculty teaching in ALCs across the United States uncovered six challenges, including: creating an overall awareness of the learning environment compared to traditional classrooms; fomenting a willingness amongst faculty to engage with the classrooms; developing a support program to meet the needs of faculty; ensuring that technology does not interfere negatively with teaching; and providing support to address technology malfunctions and barriers (Montiero, 2012).

In order to better understand the perceived barriers and technology adoption factors encountered by faculty, I conducted a pilot study focused on instructors who were making their first transition to an ALC environment, (Wheeler, 2015). Employing a quantitative survey instrument and a qualitative semi-structured interview protocol, I found that, in addition to the pedagogical changes, faculty also experienced technology adoption barriers as they began teaching in the space. Faculty reported adopting only a subset of the available equipment in the classroom. The study highlighted three first-order (i.e., teacher-extrinsic) barriers to adoption in TBL classrooms, including lack of time, lack of equipment, and lack of support. The study found two second-order (teacher-intrinsic) barriers, including faculty's attitudes towards technology and their philosophy of teaching. However, the research did not find many other commonly-cited barriers, including lack of teacher confidence and negative attitudes toward adopting technology. These ALC classroom spaces were designed for all disciplines to be technology-rich (Hutton, Davis, & Will, 2013). The lack of equipment was an unexpected finding. It highlighted the need for more research on cross-disciplinary, mixed-methodological strategies in active learning spaces as called for in the literature (Brooks & Solheim, 2014; Whiteside, 2014).

ALC Pedagogical Training

In general, pedagogical training is a major focus for research universities' teaching and learning centers (Gillespie & Robertson, 2010). A growing number of institutions offer year-long faculty development programs to support instructors in transitioning to ALCs. Montiero, (2012) conducted research on pedagogical training for ALCs and found, "five of six schools interviewed had a faculty development program for active learning, or offered a variety of programs ranging from in-class observation of active learning and basic information sessions, to more complex programs requiring application and acceptance" (p. 44).

In order to understand the pedagogical support models for ALCs, I spoke with faculty development coordinators at three institutions launching new ALC training programs. I consulted with them regarding how these training programs, under the rubric of Faculty Learning Communities (FLC), developed, and the needs that they addressed for faculty, including the transition to a technology-rich environment. The coordinators at these institutions described fellowship programs for faculty training, as summarized in the table below.

Table 1

ALC Faculty Development Fellowships

University	Fellowship	Duration/Faculty	Stipend
Univ. Indiana Bloomington	MOSAIC	1 yr./10 faculty	$1500
Univ. Rhode Island	Grand Teaching	1 yr	$1000
Univ. Massachusetts, Boston	TEAL Fellow	1 yr./12 faculty	

Note: This is a partial list of universities offering pedagogical support in ALCs.

Monteiro (2012) found that each university reported different faculty development challenges related to teaching in technology-rich learning space. These included the faculty's awareness of ALC differences, the goal of making technology invisible so that it did not interfere with teaching and learning, the development of programs that met the needs and experiences of all faculty, malfunction issues in technology; the knowledge to address faculty concerns and barriers, and an overall willingness of faculty to experiment with new technology. The results of this study indicate that, however technology-rich ALCs are compared to traditional classrooms, faculty often utilized only a small portfolio of technology tools in combination with bring-your-own-device. Findings from this research suggest that one-on-one support with someone knowledgeable about active learning teaching methods for faculty in ALCs holds the highest impact for instructors.

Research conducted by Florman (2014) at the University of Iowa underscored the importance of university-wide support from the Provost in order to foster the adoption of ALC learning spaces in addition to the pedagogical support needed to pivot between a traditional classroom and a student-centered teaching and learning. Faculty “buy-in” was deemed critical from their research; faculty buy-in included a multi-pronged approach that incorporated faculty-led workshops on active learning to national leaders presenting at institutes. The key conclusion is that building new learning spaces alone has not ensured that instructors will change their pedagogical practices to take advantage of the design (Carr & Fraser, 2014). To be effective, new resources must be coupled with varied support for faculty that helps them to integrate technology in their pedagogy.

Faculty Development

Faculty development is a dynamic field that connects a variety of resources to support the professional development of higher education instructors. Francis (1975) defined the field as an institutional process that changes the skills, attitudes, and behaviors of faculty members while improving their competence. Effective programs elicit changes in the way faculty feel about their roles at an educational institution and increase their ability to perform their jobs. For example, instructional development, a subset of faculty development, provides specific and intensive training regarding classroom skills. The tacit assumption underlying all faculty development programs is that “when faculty learn more about teaching, they teach better, which in turn improves student learning” (Rutz, Condon, Iverson, Manduca, & Willett, 2012, p. 41).

In order to contextualize the challenges of providing pedagogical support to faculty in an effort to better ensure positive outcomes in their transition to ALCs, a brief overview of the history of faculty development is provided next, followed by a discussion directly related to supporting faculty development in technology in particular.

Brief History of Faculty Development

Much research has linked professional and faculty development with student learning and achievement (Bayar, 2014; Kennedy, 2016; Neuman & Cunningham, 2009; Y Steinert et al., 2012). Faculty development encompasses many programs that support an instructor with teaching, research, and service. The major focus of this historical overview centers around the professional development of instructors with regards to the first of these, teaching and learning. While faculty members have been said to be "the greatest resource in a college program" (Mohr, 2016, p. 17), they typically are not required to receive training in teaching and learning at educational institutions, despite the status of teaching as a core skill in fulfilling their mission. Higher education professionals have often received development, growth, and feedback on their subject matter expertise without necessarily encountering support for the praxis of teaching (Gibson, 1992; Gillespie & Robertson, 2010; Sorcinelli, Austin, Eddy, & Beach, 2006).

Faculty development is a broad field that primarily assists those in teaching roles by focusing on the improvement of teaching itself. It was initially defined approximately sixty years ago as classroom-based activities that modify attitudes and skills of faculty members to help students learn. Ouelette (2010) states that, "faculty development, as we understand it today, began to emerge in U.S. higher education in the social and economic turbulence of the late 1950s and 1960s" (p. 4). The need for faculty support arose from a response to the increased presence of graduate teaching assistants and changing student demographics (Little, 2014). Faculty development frequently occurs within centers for teaching, which today provide professional development, recognition, and reward (Palmer, Holt, & Challis, 2013).

Sorcinelli et al., (2006), defined five distinct developmental phases of faculty development as a discipline, each progressively expanding the scope of faculty development beyond faculty's subject matter expertise: Beginning in the 1960's, the first was the Age of the Scholar, which sought to improve scholarship practices in a faculty's own discipline. This was followed by the Age of the Teacher, whose focus was on teaching as well as research, and coincided with the growth of student enrollments across American colleges and universities. Third was the Age of the Developer, which witnessed the rise of many dedicated centers for teaching and faculty development programming initiatives. The fourth was the Age of the Learner, which helped facilitate student-centered teaching practices and included a number of additional collaborative faculty development initiatives, such as writing and career advancement programs. Finally, during the Age of the Networker, which began in approximately 2006, faculty developers arrive at the field much more from a variety of practitioner backgrounds as compared with previous Ages in their transition into faculty development roles. At the same time, departments and support staff across many institutions began to provide a variety of educational activities for instructors on their campuses (Ouellett, 2010; Sorcinelli et al., 2006). The Age of the Networker broadened the field of faculty development to include activities such as personal development, instructional development, and organizational development (Ouellett, 2010; Sorcinelli et al., 2006).

Recently Beach, Sorcinelli, Austin, & Rivard (2016) revisited their Ages model from a decade earlier and concluded that the field had entered a new era: the Age of Evidence. Faculty developers were increasingly collaborating on a variety of institutional priorities, especially those regarding the expansion and growth of new technologies for research and teaching (Beach et al., 2016). Since 2006, the term "educational development" evolved to become nearly synonymous with the term "faculty development" in order to incorporate and more accurately represent the field (Little, 2014). Little says, "This diversity of role, context, expertise, and purpose is both a potential tension and a potential strength for the practice and scholarship of educational development" (p. 3). Diversity in the backgrounds of faculty developers provides opportunities for collaboration and instructional support that can provide instructors of all disciplines with assistance related to many facets of teaching (pedagogical methodology, integration of classroom technology, etc.).

Today, many faculty development centers exist to support the professional development of faculty and help them to facilitate teaching and learning in their classrooms (Austin & Sorcinelli, 2013; Mohr, 2016). These centers help faculty to navigate their multiple roles of teaching, research, and service (Austin & Sorcinelli, 2013; Cook & Kaplan, 2011; Mohr, 2016). The relatively recent growth of the faculty development field and its practitioners' interdisciplinary backgrounds means that the majority of faculty developers are new to the field, often with fewer than 10 years of experience in faculty development (Beach et al., 2016; Little, 2014; Sorcinelli et al., 2006). Over the past sixty years, the field of faculty development has transitioned to a collaborative, faculty and practitioner support role that incorporates a variety of personal and professional expertise in the support of college and university faculty.

But the mission of faculty development to empowering instructors by supporting their growth and professional development as educators has encountered significant obstacles given its perceived expense. When it comes to training advanced subject-matter experts, who often possess terminal degrees in their field, an emphasis on the improvement of teaching skills in addition to research is often challenging. The situation for the instructor in research institutions is particularly difficult. For such institutions, "it may be difficult to justify spending resources on additional opportunities for faculty highly qualified to manage learning within their disciplines to learn about teaching" (Condon, Iverson, Manduca, Rutz, & Willett, 2016, p. 1). At the same time, faculty development's twin foci on both empowering instructors and encouraging research has helped faculty development establish itself as a collaborative and integral part of the pedagogical development of instructors at research institutions. Today, research universities that emphasize scholarship must also balance faculty research with greater support for the teaching practice of their faculty. Nearly 65-75% of research institutions have a center for teaching and learning (Gillespie & Robertson, 2010, p. 277). Thus, even though administrators may balk at the cost of dedicated faculty development centers, the field of faculty development has proliferated in recent years and made a home for itself in the American university. The variety of faculty development programs underscores how the importance of improving university teaching is now institutionalized.

Faculty Development Activities and Gauging Effective Faculty Development

Professional development of faculty frequently focuses on the improvement of teaching skills, enhancing student learning, instructional development, curriculum experience, and organizational development that supports the mission of the institution (Gillespie & Robertson, 2010). Faculty development programs employ a variety of techniques to achieve their goals, such as individual consultations; faculty learning communities (FLCs); classroom observations; mid-semester evaluations; grant supported teaching development initiatives; scholarship of teaching and learning (SoTL) research studies; workshops; and multi-day institutes (Brinko, 1990; Cox, 2004; Gillespie & Robertson, 2010; Ouellett, 2010; Sorcinelli et al., 2006). Of the faculty development techniques, the provision of direct and timely feedback on instructors' teaching praxis has emerged as one of the most vital, if under-utilized, aspects of faculty development.

Both faculty development and professional development are broadly defined, and there is a lack of cohesive definition of critical features for its effectiveness (Kennedy, 2016). Effective professional and faculty development typically involves a multitude of factors (Bayar, 2014; Kennedy, 2016; Neuman & Cunningham, 2009; Y Steinert, Naismith, & Mann, 2012). Attempts to define these features have yielded some level of consensus, including meeting the needs of both instructors and schools, involving instructors in the design of activities; and facilitating active participation in activities and long-term engagement (Bayar, 2014). In a meta-analysis (Y Steinert et al., 2012), researchers investigated 111 faculty development studies for key features. These included high satisfaction, increased faculty confidence through participation, and increased awareness of effective educational practices (Y Steinert et al., 2012). Other features of effective faculty development programs that have been found include experiential learning, feedback, reflection, and institutional support (Y Steinert et al., 2012).

In order to support pedagogical development, faculty developers frequently employ consultations and observations of teaching to provide feedback about teaching practices (Blackmore & Blackwell, 2006; Brinko & Menges, 1997; Gillespie & Robertson, 2010; Sorcinelli et al., 2006). Faculty development consultations are meetings between an instructor and a faculty developer that provide an opportunity to discuss faculty-related matters, including teaching and learning. Observations are often administered by a faculty developer in a classroom setting, and the teaching observation data is then reflected back to the instructor. By providing instructors with options, resources, and support, consultations not only improve the practice of teaching, but encourage faculty to take responsibility for their own development as teachers (Brinko & Menges, 1997). Teaching observation protocols are frequently employed by faculty developers in order to help gather data about teaching strategies and to reflect back insights about a faculty member's instructional techniques (Brinko, 1993; Brinko & Menges, 1997; Ebert-May et al., 2011a; Gillespie & Robertson, 2010; Sorcinelli et al., 2006). According to Brinko (1993), feedback for faculty has been found to be most effective when the information is gathered from a number of sources, including faculty themselves, and when feedback is focused, descriptive, immediate, and addresses instructional behavior. Despite the availability of numerous resources on classroom observations, the actual application of classroom observations in faculty development is uncommon (Condon et al., 2016). However, the fact that faculty have been found to over-report self-change in other instruments indicates that classroom observations are a valuable tool that should be use more often (Ebert-May et al., 2011b).

In terms of instructor feedback, faculty report a preference for one-to-one training with an educational consultant, as well as the opportunity to share ideas learned with fellow colleagues (Tyrrell, 2015). Furthermore, effective faculty development programming revolves around those initiatives that meet the needs of the instructors (Austin & Sorcinelli, 2013; Gillespie & Robertson, 2010; Sorcinelli et al., 2006; Tyrrell, 2015). According to Dee and Daly (2009) who studied faculty development at seven institutions, faculty members' own needs were the most important aspect of programming. This includes pedagogical reflexivity as well as fostering the opportunity for pedagogical transformation through faculty agency (Dee & Daly, 2009).

Faculty Development in Technology

Increasingly, faculty use of technology in teaching is a major focus for the field of faculty development (Beach et al., 2016; Brinko & Menges, 1997; Gillespie & Robertson, 2010; Sorcinelli, 2002; Sorcinelli et al., 2006). Faculty development in technology is an emerging field bridging the gaps of information technology, faculty development, and other campus support functions (Collins, 2014; King, 2002; D. L. Rogers, 2000; Whitelaw, Sears, & Campbell, 2004). Faculty development initiatives complement other campus services, such as libraries, online learning departments, and information technology/instructional design departments that support instructors (J. S. Collins, 2014; Meyer & Murrell, 2014; Moore, Fowler, & Watson, 2007). As a result, research on faculty development and technology integration is emerging (Dahlstrom & Brooks, 2014; Elliott, Rhoades, Jackson, & Mandernach, 2015; Johnson et al., 2015; Mcquiggan, 2012).

Given the institutional adoption of education technology tools, along with increased expectations for technology-rich learning experiences, faculty development in these areas is vitally important. As Austin and Sorcinelli (2013) have written, "The rapid explosion of new technologies requires faculty members to integrate technology into their traditional courses and, at many institutions, learn to teach in blended and online environments" (p. 90). However, achieving this level of integration can be difficult, especially in ALCs where instructors must adapt to student-centered teaching approaches in addition to technologically-enriched classroom spaces.

The challenge of teaching in a radically different learning environment, combined with the increased presence of technology in that classroom, require an investigation of the unique barriers and technology adoption practices in these spaces.

Education Technology in Classrooms

There is an emerging consensus that constructivist classroom design augmented with an ample supply of easy-to-use technology, along with proper pedagogical training, can ultimately to help improve student learning (P. M. Baepler et al., 2016; Beichner et al., 2007; Carr & Fraser, 2014; Gebre et al., 2014; Van Horne et al., 2014). Education technology is broadly defined in higher education, and can refer to a wide variety of technology, ranging from classroom hardware to online technology (Johnson et al., 2016).

Education technology allows instructors to quickly present information, and it enables students and instructors alike to share various pieces of information and media from the web. Education technology has transformed communication by allowing students to collaborate and communicate in ways that improve their educational outcomes (Johnson et al., 2016; Laster, 2012). Education technology can be used to allow students to flexibly engage with content from a variety of locations and engage in more self-paced learning activities, particularly in blended and flipped courses (Linder, 2016). Technology in the classroom also presents a variety of undesirable issues in the classroom, ranging from distracted students to non-education web-browsing and socializing (Alfahad, 2012).

The impact of education technology on student learning, particularly in the classroom setting has been studied and debated for several decades (Bielaczyc, 2009; Clark, 1994; Kozma, 1994; Schmid et al., 2009). The important scholarly debate of Richard Clark and Robert Kozma took center stage in the 1990s. Clark (1994) argued that instructors' teaching methods had a greater impact on student learning than technology or media, which represent delivery devices. Thereby, Clark essentially rendered technology's role as minimal or non-existent. His research focused on the authenticity of problems and tasks that correlated with improved student learning. Conversely, Kozma (1994) argued that proper use of "technology, symbol systems, and processing capabilities" (p11) could have a positive impact on the cognitive skills of students and saw many unrealized opportunities for technology to help learners conceptualize, collaborate, and learn more.

On a more granular level, a recent meta-analysis (Schmid et al., 2009), found three important characteristics associated broadly with classroom-based technology. First, technology use appears to have limits with regard to impacting learning achievement. Second, technology use that supports cognition produced better results than technologies used to present or deliver content. Finally, conditions of low and moderate technology saturation led to larger effects than more saturated classrooms.

As the above research illustrates, an ongoing debate exists about the value of education technology and teaching. On one hand, many proponents advocate for improved technological literacy and training for faculty, and on the other, there are calls for pedagogical development for higher education instructors. But the two are not mutually exclusive, and the literature provides ample research regarding both the overall value and impact of education technology for student achievement, as well as the associated support needed to help instructors and students maximize its potential.

Technology Adoption and Barriers to Technology Adoption

At the same time that the effects of education technology are investigated more deeply, there are also many adoption factors and barriers that still need to be studied in order to improve the integration of education technology in the classroom, especially in the context of student-centered teaching approaches and Active Learning Classrooms.

Technology Adoption Factors

Adoption research typically investigates a tool's usefulness, the advantage it provides, and an individual's commitment to applying that tool for teaching (Reid, 2014; Straub, 2009; Xu & Meyer, 2007). Technology adoption factors are well studied both in K-12 and pre-service teacher settings (Leech, 2010; Macentee & Wells, 2005), as well as in traditional higher education classroom settings (Keengwe et al., 2010; Kuker, 2009; Lin et al., 2014; Mrabet, 2009). Adoption factors for learning technologies are highly nuanced, contextual, and may be viewed as "a learning process for individuals and organizations" (Wilson et al., 2002, p. 295).

In contrast to the literature regarding technology barriers, there is no consensus on the categorization of adoption factors in the technology literature (Gagnon et al., 2012). Adoption factors are examined in the literature through a variety of other theoretical frameworks, including Rogers' (2003) diffusion of innovation, and Lave and Wenger's communities of practice (1991) models. Several studies regarding faculty and learning technologies have addressed adoption using the Technology Acceptance Model (TAM) and self-efficacy theories (Buchanan et al., 2013; Dadayan, Dadayan, Ferro, & Ferro, 2005; Medlin, 2001; Saadé et al., 2007). These studies include deep investigations of the perceived usefulness of a technology tool and the decision to adopt.

Butler and Sellbom (2002) identified several first- and second-order technology adoption factors that are most relevant in higher education. The first-order factors are the reliability of technology, knowledge of how to use the technology, difficulty in using technology, and institutional support for using the technology. Several studies illustrate a lack of resources, particularly a lack of university resources and administrative support or more structural constraints, influence technology adoption (Al-Senaidi, Lin, & Poirot, 2009; Buchanan, Sainter, & Saunders, 2013; Nicolle, 2005). The main second-order factor cited is a belief that technology improves learning (Al-Senaidi et al., 2009; Lin, Huang, & Chen, 2014). Though these factors may be as applicable to ALCs as to traditional classrooms, adoption factors are only beginning to be studied in non-traditional or active learning spaces like ALC classrooms (Fraser, 2014; Van Horne et al., 2014, 2012).

Technology Adoption Barriers in Education

Barriers to technology adoption have been studied with respect to primary and secondary school classrooms and, as most relevant to the current discussion, in higher education, albeit in traditional classrooms (Ertmer, 1999; Ertmer, Ottenbreit-leftwich, & York, 2006; Mrabet, 2009; Reid, 2014; Schoepp, 2005; Wilson, Sherry, Dobrovolny, Batty, & Ryder, 2002). Because these barriers are also present in ALCs, and because the research surrounding traditional classrooms has yielded a number of useful frameworks, they merit review.

Ertmer (1999) formally classified barriers into first-order and second-order categories, a distinction that remains relevant. First-order barriers are “those obstacles that are extrinsic to teachers” (p. 50), while second-order barriers are intrinsic to the instructor and “interfere with or impede fundamental change” (1999, p. 51). For example, first-order barriers might include the imposition of a time constraint, or the provision of technological equipment inappropriate for a needed lesson. Second-order barriers represent intrinsic beliefs or ideas about technology, and may include the belief that laptops impede student learning, or that mobile phones should be banned from class.

Reid (2014) provided a comprehensive synthesis of many categorizations of barriers in the literature that will likely serve as a benchmark for future research on barriers to technology adoption. Reid’s analysis sets forth a fishbone framework including five types of barriers to the adoption of instructional technologies: process, administration, environmental, faculty, and technology (that is, the reliability and complexity of technology as well as an institution’s access to it). Reid’s barriers largely coincide with the first four of Ertmer’s (1999) five-category framework. Reid’s definition of the process barrier includes challenges with project management, support (or lack thereof) for those using technology, and professional development related to technology and teaching. The environmental category includes the effectiveness of education technology, legal issues with adopting technologies, tensions between academia and the administrations, and shifting organizational changes. The administration category describes issues of compensation, recognition, rewards, and institutional support. Where these four categories represent first-order barriers, the remaining fifth category, faculty, represents a second-order barrier, and encompasses participation in professional development, perception of quality and effectiveness in technology, self-efficacy and background with technology, faculty resistance to change, and their own effective use of tools.

Barriers are often described by scholars either in terms of resources that are insufficient or nonexistent (Buchanan, Sainter, & Saunders, 2013; Butler & Sellbom, 2002; Lin, Huang, & Chen, 2014; Reid, 2014). In particular, barriers frequently cited in the literature include a lack of institutional support, lack of financial support, and lack of time (Butler & Sellbom, 2002; Lin, Huang, & Chen, 2014; Mrabet, 2009; Nicolle, 2005). Other barriers include lack of training, lack of equipment, lack of functioning equipment, and loss of enthusiasm (Amundsen & Wilson, 2012; Lin et al., 2014).

Regarding faculty descriptions of barriers, the most frequently cited first-order barrier noted in the literature on technology adoption is a lack of time, followed by other issues related to access and understanding of technology. The lack of time factor bears additional explanation. Lack of time has been characterized variously in the literature, with needs ranging from time to plan, time to collaborate, time to prepare and use technology, uninterrupted time to utilize technology, time for training, and time for personal exploration and experimentation with technology (Kagima & Hausafus, 2001). Faculty report technology tools to be overly time-consuming to fit into their teaching (Al-Senaidi, Lin, & Poirot, 2009; Anderson, Varnhagen, & Campbell, 1998; Lin et al., 2014).

Faculty also report a lack of funding or institutional support when implementing new technologies (Anderson et al., 1998; Buchanan, Sainter, & Saunders, 2013; Lin et al., 2014). Additional barriers identified in the literature were lack of reliable technology equipment, lack of training, lack of technology support, and scheduling difficulties (Bennett & Bennett, 2003; Buabeng-Andoh, 2012; Buchanan et al., 2013; Butler & Sellbom, 2002; Ertmer, 1999; Grunwald, 2004; Lin et al., 2014; Mrabet, 2009; Nicolle, 2005; Reid, 2014; Schoepp, 2005; Wilson et al., 2002).

Second-order barriers revolve around teachers' beliefs or epistemologies, teaching philosophies, perceived alignment of technology with teaching, and lack of motivation (Ertmer, 1999). These barriers may also include teacher attitudes, such as confidence, negativity, perceptions that a tool is not useful, and technology resistance (Al-Senaidi et al., 2009). Researchers have also found second-order barriers in the form of technology's compatibility with an instructor's existing beliefs about the value of the tool, and with the instructor's overall philosophy of teaching (Bennett & Bennett, 2003; Buabeng-Andoh, 2012; Buchanan et al., 2013; Ertmer, 1999; Grunwald, 2004; Nicolle, 2005; Reid, 2014; Schoepp, 2005; Wilson, Sherry, Dobrovolny, Batty, & Ryder, 2002).

All of these technology barriers are compounded in ALCs, where faculty experience additional and unique challenges when teaching (Van Horne et al., 2014, 2012). The pedagogical pivot, or the transition to active learning strategies in ALCs, receives much attention in the research, especially as active learning strategies continue to be constructed across institutions of higher education (Foote, 2014). As recent research shows, the location "where these [technology adoption] issues surface often depends on the type of teaching context, and thus it is essential to determine particular problems in order to sustain better Information and Communication Technology (ICT) use" (Lin et al., 2014, p. 102).

The rate of pedagogical and technological change across higher education underscores the importance of supporting technology integration with faculty development initiatives.

Technology Integration Models

With the influx of new college classroom technology, current conversations about effective teaching frequently include discussions about ways to integrate technology to improve and promote student learning (Beach et al., 2016; Benson & Ward, 2013; Rienties, Brouwer, & Lygo-Baker, 2013; Sorcinelli et al., 2006). Recognizing this need, technology integration with teaching and learning has grown into a vital area of interest itself. Whiteside (2014) questions the state of current learning spaces with regard to technological integration as follows:

> physical classroom spaces have not caught up with digitally enhanced pedagogies. With extraordinary technological advances emerging …how have the majority of our physical classrooms not kept pace with the changing times as well as instructors' and students' growing needs? (p.96).

Importantly, high-level users of technology have been found to discuss the alignment between teaching style and technology use, while lower level users of technology have been found to have a more resistant attitude to technology (Spotts, 1999). Researchers have found that faculty with strong technology literacy may be more apt to integrate their technology literacy into the design of course assignments (Georgina & Olson, 2008).

Many scholars suggest that colleges and universities should provide professional development support that focuses on the integration of technology with teaching because increasing faculty confidence in technology literacy and pedagogical application leads to greater and more effective adoption. Furthermore, they advocate the implementation of several theoretical frameworks that support this initiative in order to increase the instructors' technological confidence and literacy. These theoretical frameworks include TPACK, SAMR, and the Rogers Diffusion of Innovations theories.

The TPACK Model

The Technological Pedagogical Content Knowledge (TPACK) model was developed by Mishra and Koehler (2006) and emerged from the Pedagogical Content Knowledge (PCK) framework pioneered by Shulman in 1986. Martin and Koehler found that learning was most effective when instructors have an understanding of the complexities shared between their content knowledge, technology knowledge, and pedagogical knowledge (Rienties et al., 2013). Content knowledge refers to subject matter that is to be taught. Technological knowledge refers to the skills required to utilize technologies in the classroom. Pedagogical knowledge describes the processes and practices implicit in teaching, from classroom management to assignment and syllabus design.

Referring to the intersections between three kinds of knowledge (content, pedagogy, and technology), the TPACK model "attempts to capture some of the essential qualities of teacher knowledge required for technology integration in teaching, while addressing the complex, multifaceted, and situated nature of this knowledge" (Mishra & Koehler, 2006, p.1017). One strength of the TPACK framework is its emphasis on the overlap between its three domains. Based on the three base types on knowledge, Mishra and Koehler (2006) defined six interrelated foundational components of TPACK, the last three of which reflect this overlap: (1) technological knowledge (TK), (2) content knowledge (CK), (3) pedagogical knowledge (PK), (4) pedagogical content knowledge (PCK), (5) technological content knowledge (TCK), and (6) technological pedagogical knowledge (TPK). The overlapping types may be summarized as:

1. Pedagogical Content Knowledge (PCK) – discipline-specific teaching and the approaches that best fit the subject-matter's content and how to scaffold the learning process.
2. Technological Content Knowledge (TCK) – involves how technology can afford newer ways of representing content to students and the associated benefits of using these approaches.
3. Technological Pedagogical Knowledge (TPK) – the ability to navigate a variety of educational tools that can be selected from for teaching a particular discipline.

Combining these interrelated domains enhances the value of each domain and provides more powerful modes of theory to apply to faculty development.

According to Mishra and Koehler:

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical

> techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (Mishra & Koehler, 2006, p. 1209).

TPACK is widely adopted in K-12 educational settings, but less so in higher education, with the exception of online instruction, where it has gained traction (Benson & Ward, 2013; Psiropoulos et al., 2014). Recent research on TPACK in higher education has been conducted and synthesized by two large meta-analyses that address the evolution of the TPACK model and the theoretical and practical applications of TPACK. These studies provide an updated understanding of the evolution of TPACK.

First, in a survey of 61 journal articles that measured TPACK and strategies for developing TPACK, Voogt et. al. found that TPACK has evolved into its own domain , emerging as a dynamic interplay between the subdomains that constitute it (Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013). Most importantly, the authors stipulate that instructors need to demonstrate technological expertise related to their subject matter in order to enhance student learning. However, adequate instruments to measure this area of technological and subject matter expertise were lacking at the time the study was conducted. The authors called for more research on teacher beliefs and practical knowledge, as well as more subject-specific research studies. Second, in research synthesizing 74 articles regarding TPACK conducted by Chai et. al., the authors found that 63% of the studies were general studies involving technology, while 37% of the studies utilized subject-specific technologies (Chai, Koh, & Chin-Chung, 2013). The authors indicate that further research was needed in the domain of technology environments with links to student learning outcomes in addition to a better understanding across a variety of disciplines.

The SAMR Model

The Substitution, Augmentation, Modification, Redefinition (SAMR) Model provides another framework for understanding the role of technology in teaching. The model describes four progressive stages of development with technology: substitution, or "S," represents the most basic level of technology integration, whereby the technology itself substitutes for another practice in the classroom; augmentation "A" represents an application of technology that supplements a traditional approach to a non-technological tool; modification, "M," allows technology to play a more significant role and may redesign the way that concepts are taught. The "R" for redefinition allows for completely new ways of teaching that are predicated on the use of new technology. Both substitution and augmentation are seen as having technology enhance instruction while modification and redefinition are seen as transforming instruction and teaching (Puentedura, 2016). The SAMR model is used for selecting and evaluating technology in K-12 settings, but it is not currently represented well in the literature (Hamilton, Rosenberg, & Akcaoglu, 2016). Nonetheless, SAMR provides useful models for technology adoption in the classroom.

Diffusion of Innovation Theory

Rogers' (2003) Diffusion of Innovation Theory is a widely used theoretical framework in the area of technology diffusion and adoption. Rogers defines an innovation as an idea, practice, or object that is perceived as new by an individual or group. He describes the term "diffusion" as the process in which an innovation is communicated over time among the new members of a social system Rogers, 2003). Diffusion of innovation is concerned with "perceived characteristics of the innovation" (Weigel, Hazen, Cegielski, & Hall, 2014, p. 621)." Rogers (2003) classifies adopters into the following categories which may be expressed on a bell-curve continuum:

- Innovators – Experimentalists and risk-takers who are intrinsically interested in technology
- Early Adopters – Technically sophisticated and interested in technology for solving problems
- Early Majority – Mainstream individuals; pragmatic in choices
- Late Majority – Those less comfortable or skeptical than the mainstream
- Laggards – Last to adopt if they adopt at all

Rogers' theory "provides a model for other institutions seeking a theory-based approach to study faculty adoption and diffusion of ICT [Information and Communication Technology]" (Keengwe et al., 2009, p. 24). The Diffusions of Innovation Theory is important for guiding this study because it addresses the multistep social process associated with technology tool utilization by faculty. The model follows technology users through a series of phases from exposure to the tool, to persuasion to use the tool, and finally the decision to implement the tool (Rogers, 2003).

As an extremely important factor in the field of faculty development, technology integration frameworks must be considered carefully and studied further. The technology integration frameworks described above provide several lenses for examining technology integration in higher educational settings and have underwritten research to maximize technology adoption by instructors. Taken together, they address a number of key aspects related to technology adoption, including: how technology-aided pedagogy as a discipline interacts with content mastery and traditional pedagogy; how technology use in the classroom may progress; and the levels of technology adoption. Increased application of these theories in the study of technology adoption at the university level is merited.

Conclusion

The adoption of student-centered pedagogy and Alternative Learning Classrooms to address the needs of contemporary students in higher education has grown increasingly popular. Some research suggests that students in ALC environments form stronger connections with fellow students and faculty alike, making possible effective socialization that is conducive to learning. Faculty making the sometimes difficult transition to ALCs have found ways of adapting to the abundant technologies they make available, for example, by connecting in their laptops to enhance instruction, or changing the content of screens dynamically to reflect the work of different student groups or an evolving strategy. Yet technology adoption factors and barriers to adoption in ALC classrooms persist. These include insufficient time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology. There are relatively few on-the-ground investigations of faculty's use of specific hardware in ALCs. This study helps to supplement existing research on ALCs, which to date have focused much more on student adoption than instructor challenges and preparation.

CHAPTER 3

THEORETICAL FRAMEWORK

This study is supported by experiential learning, the andragogical theory pioneered by Kolb (1984, 2014). Kolb's experiential learning theory (ELT) informed the creation of multiple research instruments including surveys, observations, and consultation guides that engaged participants in the four stages of experiential learning in Active Learning Classrooms by offering concrete experiences, reflection, conceptualization, and experimentation. This methodology provided insights into what technologies instructors adopt and how and they use them in their classroom, while also addressing their individual challenges or barriers. These theoretical constructs provide an effective lens to both understand and address technology issues experienced by instructors.

I employed a combination of action research and faculty development praxis in the Active Learning Classroom as part of the methodological design in order to gather data about the research questions. Action research is directly connected to the andragogical underpinning of Kolb's (2014) Experiential Learning Framework, allowing the theoretical framework to inform the methodological approach and ultimately the data collection activities. Action research allows the researcher to engage with the participants, in this case, providing customized concrete experiences and hands-on opportunities to learn more about the classroom technology.

Experiential Learning Theory (ELT)

Experiential learning is the "sense-making process of active engagement between the inner world of the person and the outer world of the environment" (Beard & Wilson, 2006, p. 2). The process involves active engagement and can take on many appearances ranging from play, leisure, to professional development (Beard & Wilson, 2006; Moon, 2004), Kolb's model of experiential learning was broadly informed by the works of constructivist scholars, including John Dewey (1938), Jean Piaget (1969), and Lev Vygotsky (1978). These scholars collectively affirmed that children's learning occurs through experience as they grow older, and that social interaction plays a vital role in the learning process. Informed by this concept of constructivism, Kolb created an analogous theoretical relationship for adults that linked experience with learning (Merriam & Bierema, 2014). Kolb defined the experiential learning cycle as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). Other scholars have framed the theory similarly by defining it as "something which knowledge can be derived through abstraction and by use of methodological approaches such as observation and reflection" (Kolb, 1984, p. 161).

In the context of the theory, even the notion of experience is viewed differently depending on the nature of the framework (Beard & Wilson, 2006; Moon, 2004). In education, experiential learning framework are, "often 'engineered' by the facilitator and tend to include…more objective views of what experience might be" (Moon, 2004, p. 105) Through training and development literature assumes that learning can result from the experience, if the activities are manifested 'properly' over a period of time and through a sequence of activities, experience is a “manifested ‘properly.” Kolb’s cycle can be used to underpin a process of the management of learning. For experiential learning in the training domain, this includes having an experience’ recognition of dissonance, clarifying, recollecting, reviewing feelings and emotional states, processing new ideas, eventual resolution, and possible action. (Moon, 2004). The method is sometimes perceived as “better” or more meaningful or empowering compared to other methods of learning. The empowerment aspect may come from the way the method is used rather than the learning form itself (Moon, 2004).

The process of learning, according to Kolb (2014), stipulates six aspects of learning which are summarized below. First, learning is known as a process, not simply the outcomes, which means focusing on feedback. Second, learning represents a process of relearning. It involves drawing out beliefs so that topic can be investigated and integrated into the learner’s mind. Third, learning requires resolving conflicts about situations and contest. Fourth, it’s a holistic approach that includes perception, thought, and behavior. Fifth, learning occurs in the context of the environment. And sixth, learning is a constructivist process that occurs between a facilitator and a learner.

Kolb’s model stipulates a sequential approach that effective learning engages with each of the four aspects of the experiential learning model (Merriam & Bierema, 2014). Knowledge results from the combination of grasping and transforming experience” (Kolb, 1984, p. 41). The ELT model portrays two dialectically related modes of grasping experience – Concrete Experience (CE) and Abstract Conceptualization (AC) – and two dialectically related modes of transforming experience – Reflective Observation (RO) and Active Experimentation (AE). Learners must have a concrete experience, reflect on observations from the experience, and then form abstract conceptions or generalizations based on those experiences. Finally, learners test or apply their learning to new experiences (Kolb, 1984, 2014; Merriam & Bierema, 2014; Zuber-Skerritt, 1992).

In the context of Kolb's ELT model, a concrete experience occurs when a person carries out a particular action. Concrete experiences represent active participation within the environment or in this case the ALC technology. When a participants observations and insights from a concrete experience, they are combined, to abstract conceptualizations. Afterwards, these conceptualizations are applied to new experiences and combine feedback from the facilitator (Kolb, 1984). To facilitate reflective observation, experiential learning theory provides opportunities for feedback based on tangible examples, personal discussion, simulations, and is tied to an emotional experience this is particularly important for studies where experiential learning is not tied to a formal curriculum such as professional development. Experiential learning calls on participants to reflect upon their experiences from the vantage point of others' point of view. Additionally, the emotional experience of participants is important to capture in reflection as it encases the initial experience.

Experiential learning is a process of constructing knowledge that involves a creative tension among the four learning modes that is responsive to contextual demands. This process is portrayed as an idealized learning cycle or spiral where the learner "touches all the bases" – experiencing, reflecting, thinking, and acting – in a recursive process that is responsive to the learning situation and what is being learned. Immediate or concrete experiences are the basis for observations and reflections. These reflections are assimilated and distilled into abstract concepts from which new implications for action can be drawn. These implications can be actively tested and serve as guides in creating new experiences, as indicated in Figure 1 (Kolb, 2012, p. 1215 – 1219). Rather than focusing solely on outcomes, Kolb's model puts the learner and their experiences front and center by emphasizing the need to create opportunity for the learner to experience, revisit, re-learn, and re-engage with new ideas and concepts as well as concepts that they have previously learned.

According to the theory of experiential learning, individuals exhibit a preference for one of four styles: diverging, assimilating, converging, or accommodating styles (Kolb, 2014). The diverging preference means that adults learn from different perspectives and through watching others as opposed to taking action themselves. Assimilation represents an adult's preference for concise, logical approaches to situations. The converging learning preference requires individuals to find a practical use for ideas and theories, and individuals with this propensity demonstrate strong specialist or technological abilities. Accommodation learning style employs a hands-on experiential approach and is embodied through individual intuition (McLeod, 2010). These four learning styles correlate to one another across two continuum axes. The first is the processing continuum, which illustrates how learners approach a task. The second is the perception continuum, which represents an emotional response to how learners feel about the learning task. The experiential learning model is shown in the figure below.

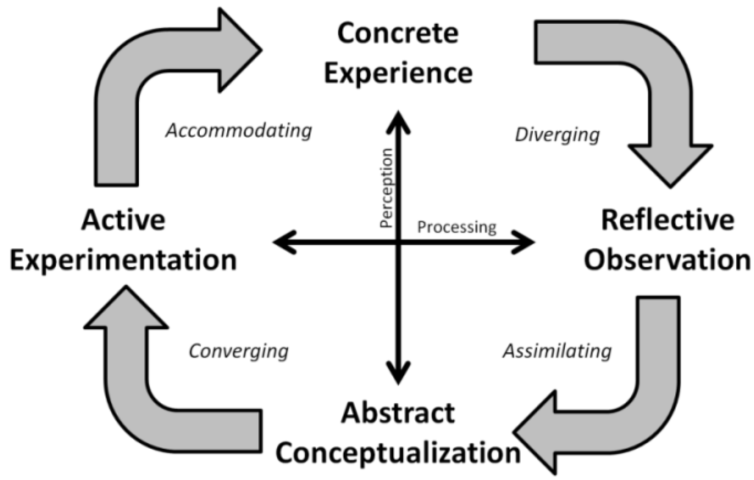


Figure 1 Experiential Learning Model

Note: Diagram of experiential learning model adapted from (McLeod, 2010).

Experiential learning provides two major limitations. First, the issue of progress, specifically, given the cyclical nature of the diagram, a learner's progression to the next "level" of experience is difficult to ascertain (Beard & Wilson, 2006; Moon, 2004). Secondly, the transferability of the experiential learning experience may or may not easily apply to other contexts (Beard & Wilson, 2006; Moon, 2004).

Experiential Learning in Active Learning Classrooms

In my study, I applied Kolb's experiential learning theory to expose and address technology adoption barriers experienced by instructors in Active Learning Classrooms. The study was designed to ensure that instructors' interactions with technology adoption followed Kolb's model: they were given opportunities to have a concrete experience of the technology; were prompted to reflect upon those experience and create generalizations; and they were guided to apply their observations directly.

The four phases of experiential learning were defined and anchored around the research instruments and the Active Learning Classroom technology, specifically with the goal of learning more about how classroom technology was utilized in the classroom. Instructors were provided hands-on training in the classroom regarding specific technologies, including the podium interface, document camera, and wall-buttons. During the study, an initial classroom consultation focusing on the usage of educational technology gave participants space to engage with and build upon their prior experience of technology in the classroom. Participants were prompted to reflect on and create abstract interpretations of that experience by a combination of a classroom observation, a survey, additional online resources, and a second classroom consultation. These resources gave participants the time, opportunity, and assistance needed to independently experiment with and reflect on the technology tools.

Conclusion

Kolb's ELT framework provided a guide for engaging participants in the four phases of experiential learning with classroom technology in ALCs. Participants were encouraged to have a concrete experience, reflective observation, abstract conceptualization, and active experimentation in order to help them overcome their unique barriers to ALC classroom technology. Additionally classroom observations and survey data provided customized and specific feedback about the classroom technology usage and adoption challenges that was reviewed with participants in this model.

CHAPTER 4

METHODOLOGY

Introduction

The methodological framework detailed in this chapter was specifically designed to provide a diverse set of qualitative and quantitative data in order to better understand the unique aspects and challenges of technology integration experienced by instructors in Active Learning Classrooms (ALCs). I developed surveys, consultation interview protocols/guides, and observation protocols using prior research, existing instruments, and Kolb's Experiential Learning Theory. I obtained Institutional Review Board (IRB) approval [Protocol ID: 2015-2864] in accordance with university policy for human subjects research (see Appendix A).

Research Questions

I studied instructor use of Active Learning Classroom technology using action research and experiential learning theory as a framework. The following research questions guided my study:

- R1: How and for what purposes do faculty use technology in the ALC?
- R2: What technology adoption factors and barriers were experienced by instructors in an Active Learning Classroom?
- R3: How does a semester-long faculty development intervention program impact instructors' adoption of Active Learning Classroom technologies?

Research Site

I selected a large research university with new Active Learning Classrooms for this research study. These classrooms were chosen because of their technology-rich designs and because of the diversity of instructor disciplines and teaching experience in these classrooms. I also conducted a pilot study pertaining to faculty's use of technology in these spaces (Wheeler, 2015), and found that faculty transitioning to ALC classrooms experienced challenges adopting technology, incorporating active learning pedagogies into their teaching, and revising their courses to include active learning pedagogies. Based on these findings, I determined that a larger study on this topic was needed to better understand Active Learning Classroom technology adoption and barriers to adoption.

The research site had recently embarked on a multi-year university-wide initiative to develop an inventory of new classroom learning spaces because ALCs were deemed essential for the campus's future growth. In Fall 2014, new learning spaces were constructed, and the new classroom spaces were equipped with the latest in education technology. The most technologically-advanced classrooms in the building are ALCs. The pictures below provide perspective on the five classrooms where the study occurred.

Classroom 1 Capacity 63 Table Laptops 21 Lectern Computer 1

Classroom 2 Capacity 81 Table Laptops 27 Lectern Computer 1

Classroom 3 Capacity 99 Table Laptops 33 Lectern Computer 1

Classroom 4 Capacity 99 Table Laptops 33 Lectern Computer 1

Classroom 5 Capacity 99 Table Laptops 33 Lectern Computer 1

Figure 2 Active Learning Classroom

Note: Configuration of Active Learning Classrooms shown, along with classroom capacity

Each Active Learning Classroom was equipped with between six and nine round tables, all capable of seating nine students per table. The classrooms were enhanced with various technologies, including three laptops and three microphones at each table, numerous HDMI-type connectors, a call button, flat screen TVs for sharing information, and whiteboards with cameras to encourage teams of students to collaborate and problem-solve in class. Additionally, a lectern podium was centrally located in the classroom. The podium was equipped with a lectern computer, HDMI and VGA-type connectors, a wireless microphone, a document camera, Apple TV, iClicker connection, Benchmark 3000 scoring system, DVD player, and two Crestron touch-screen classroom control panels which allowed the instructor to manipulate the learning environment using a variety of audio/visual technology combinations (see Appendix B for a list of the technology available in ALCs).

Active Learning Classroom Technology Tools

Technology hardware built into the Active Learning Classroom was investigated in this research study. The photos in the figure below illustrate the technology-enhanced learning space by focusing on several of the most commonly used pieces of technology equipment available to both instructors and students.

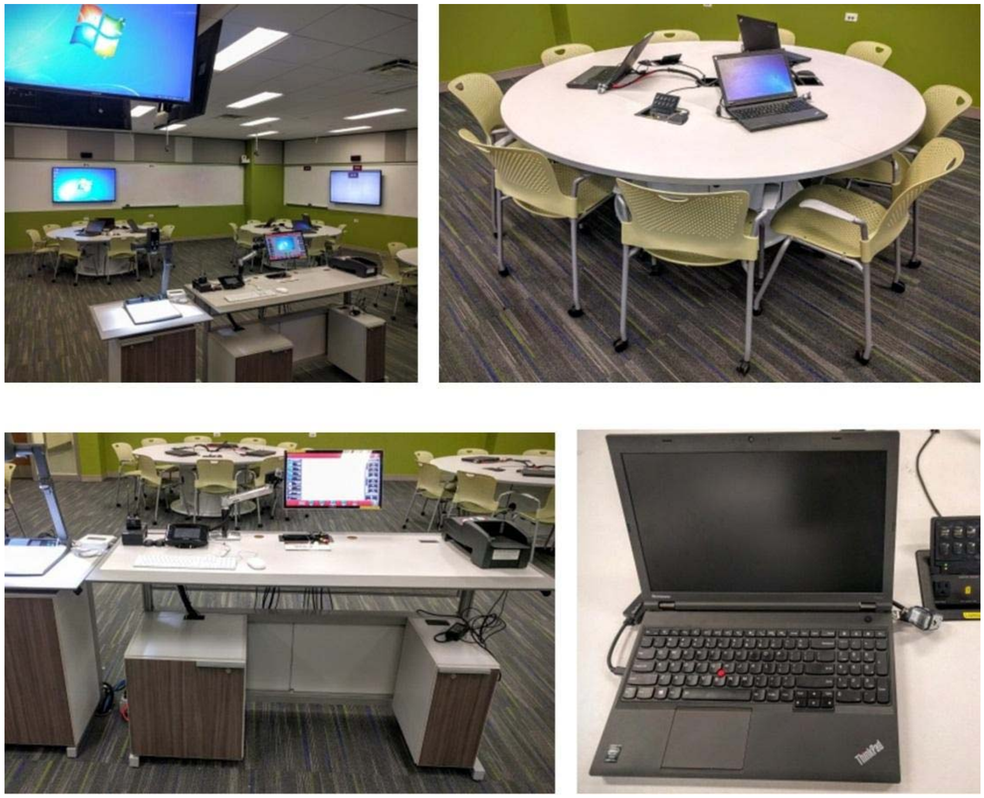


Figure 3 Active Learning Classroom
Note: Photos by Brad Wheeler, December, 2015

In total, 25 in-class technology hardware tools were examined by guiding participants through six major research instruments. Below is a description of the classroom technology tools discussed in this research study.

Table 2
Active Learning Classroom Technology Equipment

Tool	Description
	Podium Classroom Control A central stand that controls multiple audio/video feeds across the classroom. The screen doubles as the lectern computer.

Crestron Handheld Classroom Control
A portable podium control that can control many of the audio/video feeds across the classroom.

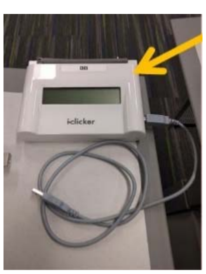
Podium Connectors
A cable cubby located at the instructor podium equipped with audio/video connectors for the instructor's portable devices.

Lectern Computer
A desktop computer available at the instructor station. The touch screen doubles as the podium classroom control.

Lectern Document Camera
A real-time image capture device or visual presenter that can display 2D or 3D objects on the LCD TV screens in the Active Learning Classroom.

Instructor Microphones
Two styles of instructor microphone are available at the instructor station: a clip-on style and a traditional handheld microphone.

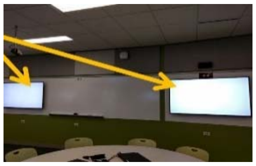
Benchmark 3000 Scoring System
Proprietary exam scanner to grade multiple choice assessments.



iClicker
Proprietary Audience Response System, with a base station built into Active Learning Classrooms. Portable student and instructor clickers must be brought to the class.

Stadium Monitors

LCD TVs mounted above the instructor station. Display can only be controlled by the instructor podium interface.



Wall-Mounted Monitors

LCD TVs mounted around the classroom, one at each student team table.

Echo360 Lecture Capture

Proprietary audio/video recording device mounted in the classroom to record the class. Instructor must request service activation through the university.

Classroom DVD Player

Built in “region-free” Blu-ray player. It can read discs formats from any of the 6 DVD region codes.

Apple TV or Wireless Projection System

Proprietary wireless projector for remotely broadcasting laptop audio and video through the instructor’s station.

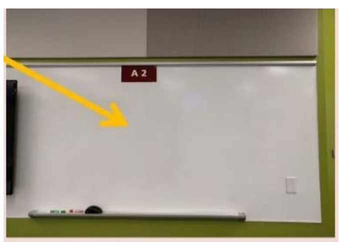
Student Table – Classroom Laptop

A laptop provided in the Active Learning Classroom (as opposed to, or in addition to, laptops students bring to class). The classroom is equipped with a 1:3 laptop to student ratio by pedagogical design.

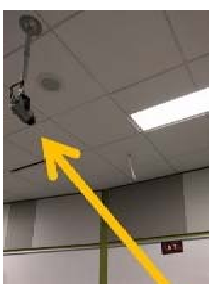
Student Table – Connector
A cable cubby equipped with audio/video connector for students to attach their personal devices. Each 9-seat round table is equipped with 3 student table connectors.

Student Table – Microphones
Button-activated microphone built into student tables. Each 9-seat round table is equipped with 3 student table microphones.

Student Table – CALL Button
A toggle button that activates the CALL indicator light. One button is available per 9-person table.



Student Table - Whiteboard
Whiteboards mounted around the classroom, one per 9-person student team table. Note: Although not electronic, whiteboards were deemed part of the classroom's technology infrastructure for the purpose of this investigation because they could be used in conjunction with the whiteboard camera to capture content.



Student Table - Whiteboard Camera
Cameras mounted around the classroom to capture each team's whiteboard display. One camera per 9-person table.

Student Table - Wall Buttons
Small buttons located under a table's LCD and whiteboards. Pressing the button pushes the table's display to other displays in the room. One pair per 9-person table.

Portable hardware tools frequently brought into the learning environment for pedagogical purposes were also included in the research. These tools included personal laptops, tablets, and mobile phones belonging to instructors and used for instructional purposes, as well as personal laptops and mobile devices belonging to students and used for engaging in classroom activities. These technology tools were included due to the increased attention education technology researchers have paid to "Bring Your Own Device" (BYOD) initiatives (Dahlstrom, 2015; Dahlstrom & Brooks, 2014; Dahlstrom, Walker, Dziuban, & Morgan, 2013; Emery, 2012). Instructors were also given the option to use additional technology equipment not noted above during any point in the study.

Study Design

As described in the literature and theoretical framework chapters, this research study is informed by experiential learning theory in higher education. Research activities, instruments, and data collection were nested within a semester timeline familiar to instructors. Further, the consultation instruments involved active participation from both the researcher and the instructor. The instructors' involvement in the study built on the previous experience of instructors through collaborative inquiry with the researcher. As a result, the action research approach allowed me to engage with and focus on instructors' competence, self-awareness, and confidence as it applied to Active Learning Classroom technology.

Action Research Methodology

Action research traces its roots to improving perceived social problems. The theory was conceptualized as a three-stage process: unfreezing structures, changing those structures, and freezing them back into an improved structure (Greenwood & Levin, 1998; Melrose, 2001). According to Dick (1993), action research is designed to “bring about change in some community or organization or program” and to “increase understanding on the part of the researcher” (p.4).

This approach is useful and beneficial for this study a variety of reasons. First, the nature of the research mirrors the normal activities of practitioner work, which means that it is authentic and natural for the participant and researcher. Second, because action research aligns naturally with ELT, it has the ability to empower both practitioners and participants through the underlying adult learning cycle. Third, it is a participative engagement between the researcher and the participants. The two-way dialogue and exchange of information adds depth and power compared to traditional one direction studies where the participant only provides information to the researcher. Fourth, the model is highly customizable, and that is helpful for meeting the participants at their level and refining it along the way to meet their needs (Dick, 1993).

Action research methodology has been used with educational research in K-12, higher education, and professional development studies (Mills, 2000; O’Hanlon, 1996; Zuber-Skerritt, 1992). Higher education research conducted by Zuber-Skerritt (1992) has been set up to be critical, reflective, accountable, self-evaluating, and participative in nature. Data collection techniques for action research in education frequently utilize a variety of tools, including qualitative collection instruments, direct observation, and inquiry through ethnographic structured interviews and questionnaires (Mills, 2000). This study employed these same instruments in order to collect a diverse set of qualitative and quantitative data. This data collection and analysis will help researchers better understand the unique aspects of technology integration for Active Learning Classroom instructors.

Recruitment

I recruited participants for the study based on several criteria. To minimize differences in classroom technologies and ensure homogeneity in the learning environment, I developed a list of instructors assigned to any one of five Active Learning Classrooms that were constructed simultaneously and equipped with nearly identical hardware configurations. I excluded courses with more than one instructor of record. All instructors of record assigned to Active Learning Classrooms were eligible regardless of rank or discipline. Previous teaching experience or pedagogical training in an Active Learning Classroom was not a qualifier for the study, as I sought to include a representative cohort of instructor experiences in my dataset.

Based on these criteria, and in accordance with general acceptance of sample sizes for such studies ranging from 4-34 participants as best practice (Saunders, 2012), I identified a total pool of 36 instructors for the Spring 2016 semester. I sent an email to each instructor of record in the Active Learning Classroom to personally invite them to join the study. I followed up with instructors I had not heard back from after one week. I also printed small recruitment handouts that were left in the classrooms and distributed by IT support staff to Active Learning Classroom instructors. From this pool of candidates, I was able to recruit 13 participants. As an incentive, participants could immediately opt in to a free drawing for an iPad mini during the initial consent process.

One participant was randomly selected at the end of the study based on policies and guidelines set forth by the Market Research Society (2012).

Participant Profile

The 13 instructors participating in this research study hailed from a variety of departments, as the Active Learning Classrooms are available to instructors regardless of discipline. Below is a table detailing the participants' demographic information. In order to protect the identities of participants, all names have been anonymized using pseudonyms.

Table 3

List of Participants

Instructor	Gender	Rank	# Current Courses	# Prior ALC Courses	Discipline
Marie	F	Other	3	1	Nursing
Lindsay	F	Senior Lecturer	1	3	Natural Sciences
Daniel	M	Assistant Professor	1	0	Engineering
Hans	M	Full Professor	1	6	Biochemistry
Mitch	M	Senior Lecturer II	2	8	Physics
Anderson	M	Lecturer	3	2	Music
Tim	M	Associate Professor	2	5	Engineering
Alexis	F	Assistant Professor	3	3	Theatre
Chris	M	Associate Professor	1.5	7	Biology
Tyson	M	Lecturer	4	0	Management

Instructor	Gender	Rank	# Current Courses	# Prior ALC Courses	Discipline
Chandler	M	Full Professor	2	0	Natural Sciences
Christi	F	Lecturer	2	2	Physics
Brian	M	Lecturer	3	3	Physics

It is important to note that this study largely attracted experienced ALC instructors. Six instructors had previously taught between one and three courses in an Active Learning Classroom, while four instructors had previously taught four or more classes in such a space. Only three of the participants were teaching in an Active Learning Classroom for the first time.

Instrument Overview

The table below provides a brief overview of the instruments. Each instrument is described in full, granular detail in the appendices.

Table 4

Table of Instruments

Phase	Instrument	Description
Signup	Signup Survey	Deployed via recruitment e-mails and a research website, this survey captured demographic information and informed consent.
Pre	Classroom Observation 1	Administered classroom observation protocol for the instructor regarding their technology use in the Active Learning Classroom.
	Survey 1	Deployed online survey to instructors at the beginning of their Active Learning Classroom course in order to identify their individual classroom technology goals, use, and perceived barriers.
	Consultation 1	Engaged in a one-to-one faculty development instructional consultation regarding the Active Learning Classroom technology and barriers and provided hands-on technology training.
Post	Classroom Observation 2	Administered a second classroom observation protocol for the instructor regarding their technology use in the Active Learning Classroom.
	Survey 2	Deployed online survey to instructors at the mid-semester of their Active Learning Classroom course in order to identify their individual classroom technology goals, use, and perceived barriers.
	Consultation 2	Engaged in a follow-up one-to-one instructional consultation regarding observation protocol findings as well as instructors' individual technology goals, use of technology, and perceived barriers to adopting Active Learning Classroom technologies.

Data Collection

Data collection activities occurred over a 14-week semester during Spring 2016. The table below describes the data collection timeline:

Table 5

Data Collection Timeline

Timeline	Instrument
Week 0	Signup
Week 2-3	Observation 1
Week 4	Survey (Pre)
Week 5-7	Consult 1
Week 8-9	Observation 2
Week 10	Survey (Post)
Week 11-13	Consult 2

Note: Timeline is approximate based on a standard participant, but was sequential for all participants enrolled in the study.

All 13 participants completed the entire semester-long study. The full compliance of all participants across all data collection points provided a complete and robust dataset for analysis.

Instrument Description

This section provides an overall description of each instrument. Further details are available in the appendices**.**

Signup & Recruitment Survey

All participants were provided with a link to a website describing the study (see Appendix C). This website informed participants about the study, including the basic requirements of participating and a timeline of activities. Participants also used the website to sign up to participate, give informed consent, and complete a preliminary demographic survey that also captured their prior teaching experience. Details about this survey can be found in Appendix E.

Informed Consent.

I collected informed consent at two points in the study. The first informed consent touch point was conducted electronically through the recruitment survey. The second informed consent touch point occurred during the face-to-face consultation phase where I reviewed, discussed, and co-signed the hard copy form prior to commencing the consultation. This informed consent form included an addendum that allowed me to capture video details of the Active Learning Classroom consultation (see Appendix D). All participants were encouraged to print their informed consent form from the online signup survey, and each received a copy of the second form at the time of the consultation. I secured original copies in accordance with IRPO protocols.

The university's Institutional Review Board (IRB) was also contacted regarding the possible need to secure student informed consent for instructor's classroom observation. The IRB confirmed that students need to be notified of the researcher's presence, but that the nature of this study does not necessitate students' informed consent. Further due diligence conversations with colleagues confirmed this practice. I spoke with faculty development centers conducting similar observational research in ALCs at the University of Indiana Bloomington and Washington University of St Louis. Both reported that student informed consent was unnecessary.

Classroom Observations

Observations are discussed in terms of observation development and observation deployment.

Observation Development

Classroom observations are important components of praxis in the field of faculty development, and they provide insight into teaching practice (Flynt, 2008; Hora, Oleson, & Ferrare, 2013; Karabulut ilgu, 2013; Ma & Lorelli, 2015; Shekhar et al., 2015). Observations provide rapid assessment as well as developmental support for both new and experienced teachers (O'Leary, 2013). Several protocols that pertain specifically to active learning spaces like ALCs have been incorporated in the development of this instrument. A basic summary of popular observation tools developed primarily for STEM and active learning environments is listed below:

Table 6

Summary Characteristics of Previous Classroom Observation Protocols

Protocol	Level	Student/Instructor	Details
RTOP	K-12	Primarily instructor	Student communicative interactions
UTOP	K-12	Instructor only	None
OTOP	UG	Instructor & student	Student discourse and collaboration
TDOP	UG	Instructor & student	Limited focus on student engagement
COPUS	UG	Instructor & student	Positive student reactions
VOS	UG	Primarily instructor	Note-taking & listening for engagement

Note: Excerpt (Shekhar et al., 2015, p. 599)

New protocols continued to be added to this body of literature during the development of this study, including Birdwell and Hammersmith's ALC protocol (2015), which was still under development at the commencement of this study. However, these protocols often addressed faculty-student interaction or pedagogical practices and ignored many of the technology-related practices in the classroom. Therefore, further investigation into a technology observation protocol was undertaken to address this gap.

I determined that the International Society for Technology Education (ISTE) Classroom Observation Tool (ICOT), conceived for K-12 settings but recently adapted for higher education domain studies as well (Bielefeldt, 2012; Flynt, 2008; Karabulut ilgu, 2013), was best for this study. The ICOT is a rubric that allows observers to assess the extent of technology integration in the classroom. It may be used by administrators for needs assessment, by technology coordinators for professional development purposes, and by individual teachers for reflective purposes (Bielefeldt, 2012). Constructivist, technology-enhanced spaces such as Active Learning Classrooms are therefore well matched for this tool.

I secured rights to use the instrument for the purposes of this research (see Appendix K) and adapted the ICOT to an Active Learning Classroom observation protocol. My protocol makes use of many items from the ICOT, but modified to capture technologies typically found in ALCs. For example, tools that were built into the classroom were substituted for ICOT items such as the digital camera, digital sensors/GPS tools, etc. The K-12 National Educational Technology Standards for Teachers (NETS-T) were removed as they were not relevant to this research study on higher education classrooms.

An important addition I made to the Active Learning Classroom observation tool was the inclusion of pre-class activity observation. The technology-enriched nature of the Active Learning Classroom, combined with reported barriers such as “lack of time,” suggested that instructors’ behaviors and use of the space immediately prior to class may impact technology use throughout the class period. Therefore, I began observing the instructor 10 minutes before class. A unique addition into this research domain, pre-class observation provides a glimpse into instructor classroom behaviors previously uncaptured in research utilizing ICOT. Full details regarding this protocol are available in Appendix F.

Observation Deployment

After consenting to the study, participants were scheduled for an observation during the first two weeks of class and a second observation during weeks 5-7. I asked participants to schedule the observation during a typical ALC class, with "typical" defined as those activities that each participant reported as common, day-to-day practice when they taught in an ALC space. In addition to giving me access to how participants use ALC technology in their teaching, this request ensured that I would not observe on a day when testing or other non-instructional tasks must be completed. This approach to classroom observations allowed me to observe only pedagogically active classes early in the semester.

During the primary observation, I sat behind the instructor lectern, away from student tables. This location allowed me to unobtrusively observe the entire classroom while simultaneously being able to view the technology equipment on the lectern. In the case of one participant, who opted to instruct from a student table rather than the instructor podium, I relocated myself to a corner of the classroom behind the instructor in order to preserve the faculty focus. I also informed all instructors that they could ask me to move at any time depending on their teaching needs.

Surveys

Given the unique ALC environment, I developed two survey instruments that were modified from a research study on faculty development in technology. The surveys provided self-reported data from instructors regarding the classroom technology's importance, usage, and the challenges instructors experienced. As part of the experiential learning and action research methodology, participants and the researcher reviewed the survey data during consultations. The instruments were derived from recent quantitative research on the topic of faculty technology adoption and barriers to using technology in the classroom (Cenzon, 2009; Reilly, 2014), as well as from recent active learning research conducted by the Research & Evaluation Team, Center for Educational Innovation, University of Minnesota (see Appendix J). Like the observation tool, the survey was modified to highlight the Active Learning Classroom technology. Survey questions were modified and enhanced using techniques provided by Fowler (2008) to ensure items would be optimized for ALC environments and other non-traditional classrooms, making them good measures of the research question.

Survey 1 (the pre-survey) included five banks of questions focusing on a variety of barriers and adoption topics for the purpose of understanding technology use in Active Learning Classrooms. The pre-survey question banks are described below:

Table 7

List of the Survey Instrument Question Banks (1 of 2)

Question Bank	Topic	Purpose
Bank 1	TBL Technology Tool Usage	Frequency of technology classroom tool use and perceived importance
Bank 2	Technology Barriers	Ratings of agreement/disagreement regarding barriers to classroom technology use
Bank 3	Attitudes about Active Learning Classroom Technology	General attitudes about classroom technology for instructional delivery
Bank 4	Consultation Questions	Formative assessment questions about challenges and opportunities to learn more about technology

Note: See Appendix E for full details

The post-survey was largely a replica of the pre-survey. In the post-survey, participants revisited questions about the classroom tools, barriers to classroom technology use, and the epistemological beliefs they held regarding technology. The goal was to help illustrate changes over time in Active Learning Classroom technology use and in the barriers that instructors report. The final bank of questions in the post-survey asked the instructor to revisit and reflect upon their experience in the study. The post-survey question banks are described below:

Table 8

List of the Survey Instrument Question Banks (2 of 2)

Question Bank	Topic	Purpose
Bank 1	ALC Technology Tool Usage	Frequency of technology classroom tool use and perceived importance
Bank 2	Technology Barriers	Ratings of agree/disagree regarding barriers to classroom technology use
Bank 3	Attitudes about Active Learning Classroom Technology	General attitudes about classroom technology for instructional delivery
Bank 4	Faculty Development Questions	Summative and reflective assessment of the faculty development model

Note: See Appendix I for full details

Consultations

Consultations provided instructors with an opportunity to discuss their classroom technology usage and challenges in conjunction with the researcher. Faculty developers frequently hold consultations with instructors which are important parts of teaching improvement (Brinko, 2012). The consultation instrument for this study was developed based on a taxonomy of technologies proposed by Caladine (2005) and on my prior experience within the Active Learning Classroom technology environment. The semi-structured nature of the consultation allowed for open dialogue and exchange. Each consultation provided an opportunity to discuss the participant's course and classroom technology.

The consultation began with warm-up questions about their teaching and about their experiences with the classroom technology. The consultation also provided an opportunity to review the participant's observation and survey data, and discuss technology challenges in the context of their teaching. It also provided an opportunity to engage in hands-on technology training for the classroom technology. I conducted all consultations in an Active Learning Classroom to allow the participant to interact with the physical technology that they used during class. Consultations were video-recorded in order to capture both conversations and interactions with the classroom technology equipment. Full details regarding the specific consultation questions are available in Appendices G and H.

Though the two consultations were similar, the second consultation was developed to maintain the integrity of the action research design and the experiential learning model. It allowed instructors to revisit technology tools or engage with ones they had not previously used. Instructors primarily enacted the last two phases of the experiential learning model (abstract conceptualization and active experimentation) by thinking about ALC technology tools in more detail and experimenting with them further.

Data Analysis

I conducted data analysis with the support of two software programs: SPSS for quantitative data and NVivo for qualitative data.

Quantitative Data

Due to the small sample size, descriptive statistics, including frequency statistics were examined to provide overall insights into the participants and the technology tools. This provided an overall view of the participants use and guided subsequent qualitative analysis. Descriptive statistics for technology tool use and importance were calculated using SPSS and charts were developed using Microsoft Excel.

Qualitative Data Analysis

I imported all qualitative data from the classroom observations and the consultation transcripts into NVivo. I organized the data into two macro-level categories so the data could be filtered by participant and instrument for indexing purposes only. I also created an attribute table for each participant that included their demographic and classroom information from the signup survey. This allowed the participant data to be further filtered by demographic category.

After the data was organized in NVivo, I created case nodes for each participant, IT tool, and each of the six instruments. NVivo's nodes are synonymous in this study with codes. In total, I developed 13 participant case nodes (one for each participant), 26 IT tool nodes representing the classroom hardware, plus one for "other" tools to emerge from the data, and finally six data point nodes (two surveys, two observations, and two consultations). I also created NVivo nodes for each of the four phases of Kolb: concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb & Kolb, 2005; Kolb, 1984). Furthermore, I created an action research code to capture data that I provided to participants, as opposed to data garnered from participants.

I used Braun and Clarke's thematic analysis guide (2006), presented below, as a framework to analyze the consultation data.

Table 9

Thematic Analysis Guide

Step	Phase	Description of the process
1	Familiarizing yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2	Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3	Searching for themes:	Checking whether the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
4	Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
5	Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Phase 1: Familiarizing yourself with your data

First, I captured qualitative video data using a DLSR video camera and a duplicate of the audio using a Zoom H4n voice Recorder. All qualitative data was transcribed using a third-party provider. I also watched all consultation videos once through to gain familiarity with the audio/visual data. Initial analysis consisted of reading each transcript thoroughly twice and creating précis memos for each participant summarizing my understanding of their experience with Active Learning Classroom technology. During this initial pass, I developed a code for "interesting" to reflect my interest as a researcher. I coded observation and consultation data to match the Active Learning Classroom technologies. In other words, observation and consultation data referencing a particular technology or technologies were earmarked to the appropriate code for the classroom technology for easy querying and future access.

Phase 2: Generating Initial Codes

Second, I generated initial codes based on interesting features of the data in a systematic fashion. I used NVivo to store these codes, referred to as nodes in NVivo, which were both prescribed from the literature and emergent or grounded in the data itself.

Prescribed codes were developed based on the barriers and adoptions literature. These included codes for first-order barriers, second-order barriers, and specific adoption factors. Additionally, four prescribed codes came from Kolb's experiential learning process, each labeling one of the four Experiential Learning theory phrases (concrete experience, reflective observation, abstract conceptualization, and active experimentation).

For easy access and deeper analysis, I coded all transcripts and observations based on the twenty-five technology classroom tools described earlier. Examples of the primary codes developed during this research are illustrated below in the figure below.

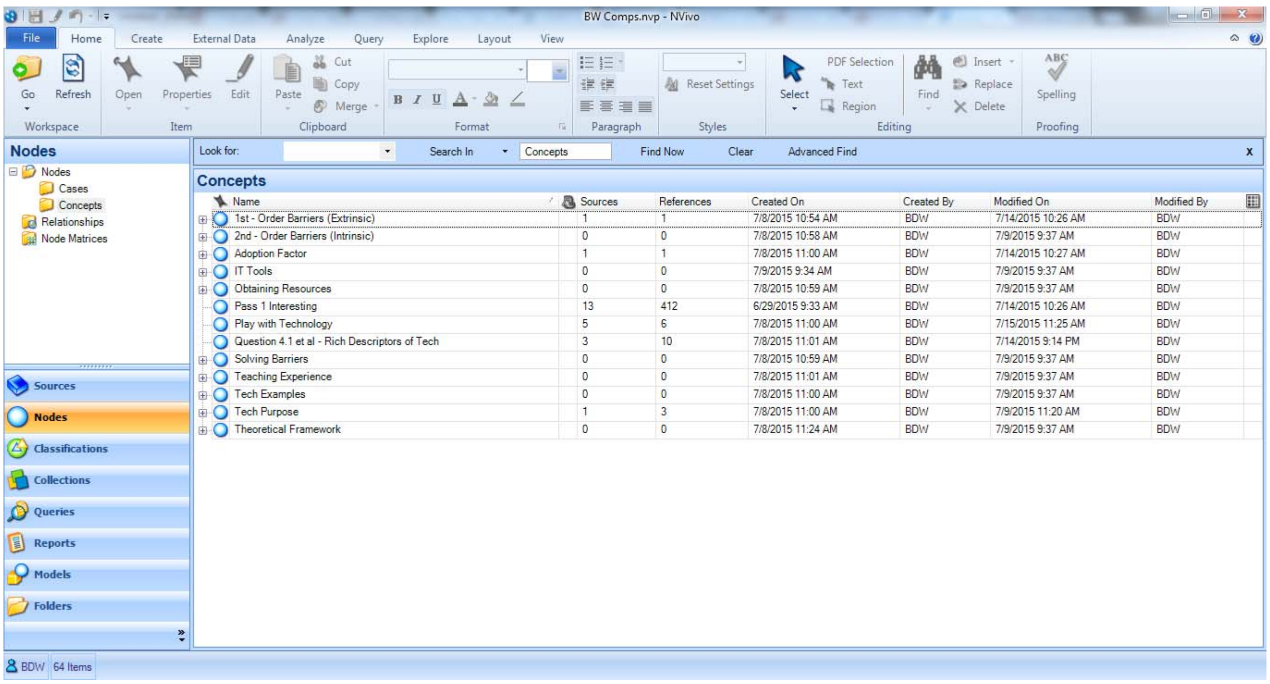


Figure 4 Thematic Codes in NVivo Used for Qualitative Analysis
Note: Constructed by following Braun and Clarke's (2006) thematic analysis guide.

To parse the data into manageable chunks, I developed emergent codes that resonated with me and the data. The codes generated initially consisted of technology tools as all data was coded with regards to the tool it described. I ran numerous cross-tab reports to illustrate technology tool usage by instructor. As I processed the data, other emergent codes included technology used for engaging students, technology used for delivering content, technology failures, prior teaching experience, and experimenting with technology. The full list of codes is listed below:

- 1st Order Barriers (Extrinsic)
    - Time to Plan
    - Training
    - Fidelity of Implementation
    - Support
        - Classroom
        - IT
        - Pedagogical
        - University OR Department
- 2nd Order Barriers (Intrinsic)
    - Age
    - Confidence
    - Epistemology
- Adoption Factor
    - Confusion over tool
    - Follow others
    - Redundancy
    - Student/TA use
- Play with Technology
- Solving Problems
    - Collaboration
    - Modelling
    - Reflection
- Teaching Experience
    - Course – Conversion
    - Course – Development
    - Course – In progress
    - Prior Teaching Experience
- Technology Scenarios
    - Failures
    - Future Plans
    - Success
- Tech Purpose
    - Deliver content
    - Engage with content
- Theoretical Framework
    - Abstract Conceptualization
    - Active Experimentation
    - Concrete Experience

Figure 5 Final Codes for Qualitative Data Analysis

In order to immerse myself in the qualitative data gathered during consultations, I developed an audio/visual process that allowed me to deeply engage with the data. I developed a process and method called the Qualitative Data Analysis Factory process that utilized one laptop computer connected to two additional external LCDs (see figure below).

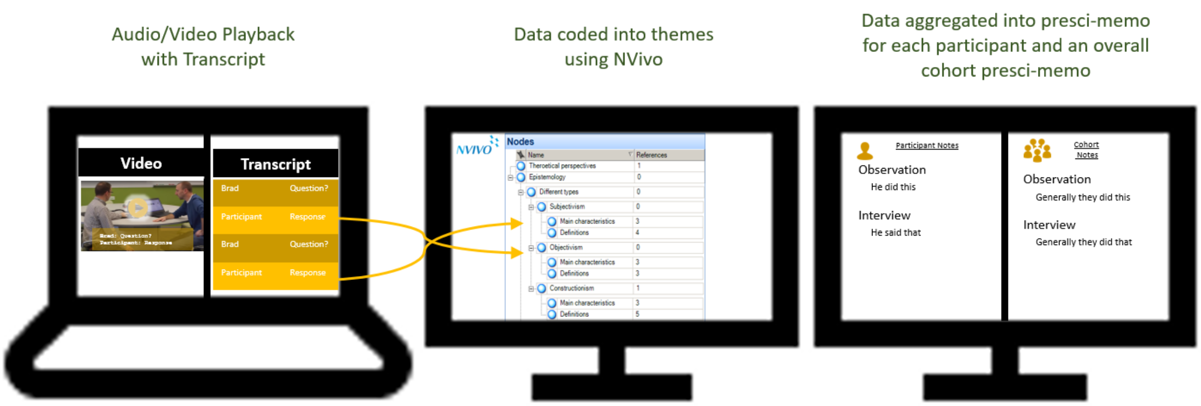


Figure 6 Qualitative Data Analysis Factory process (QDAF) model.
Note: QDAF model is an effective and efficient coding method for qualitative data using one computer and multiple LCD screens.

I played back video recordings of the instructor consultations while reading the transcript on the laptop. Having both a written and audio/video version of the data was a powerful coding tool because it allowed me to have the easy searching and formatting options of the written word without losing non-verbal communication or an exact picture of how instructors made use of their space. Viewing the video in conjunction with the transcript allowed me to understand and see the nuances of how a participant engaged with tools in a three-dimensional learning environment. This minimized the confusion when coding on screen two as participants frequently pointed, gestured, or used demonstrative pronouns when referring to technology in the classroom. The QDAF process also utilized a third LCD screen that I divided into two sections for presci-memos. The presci-memo format shown on the left was for each individual participant's notes. The presci-memo format shown on the right was for the group and provided areas where more emergent codes or cross-cutting themes could be described.

Phase 3: Searching for themes

Third, I divided the codes into potential themes that include success or failure of technology use, solving technology problems, and technology-pedagogy alignment. Themes captured important aspects of the data and represented patterned responses that were found across the instruments and from a variety of disciplines. I identified themes as I reviewed code reports from NVivo and the presci-memos multiple times. These themes began to answer the first two research questions: 1) how and for what purpose faculty use technology in the ALC and 2) what technology adoption factors and barriers instructors experienced in an Active Learning Classroom.

Phase 4: Defining and naming themes

I reviewed the emergent themes in conjunction with coded extracts and mapped the data into thematic chunks. I further defined these themes by using several documents and organizing strategies that set the framework for the results chapters. Themes represented the essence of the data and were defined from codes and refined over time that accurately and consistent account that captured and narrated data. The themes, along with rich quotes for each, were compiled into a working document that was refined and rewritten several times in conjunction with feedback from the committee. As described later in the results, major emergent themes for the first research question included student-centered technology applications and instructor-centric technology usage that was oriented to content delivery. For instructor-centric themes, the following sub-themes were found including, podium as the instructor command center, monitors for presentation broadcast, tablets as digital whiteboards, microphones for instructor amplification. Non-Instructor technology locus subthemes included LCD sharing, whiteboard sharing, and device facilitated participation.

Themes for research question two uncovered a variety of barriers and technology adoption factors. Technology adoption factors and barriers to adoption included time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting.

For the final and third research question, data was coded in accordance with Kolb's ELT framework. Data was reviewed and coded in accordance with the discrete phases, concrete experience, reflective observation, abstract conceptualization, and active experimentation phases.

Phase 5: Producing the report

Finally, I selected compelling examples, quotes, figures, and case studies for this scholarly manuscript that specifically addressed the three research questions. The aspects of the analysis chosen for this report capture and tell the complicated story of the data with a strong narrative. The themes were combined to provide a coherent, concise and logical representation to an external audience. In other words, the manuscript tells the story of the participants authentically while directly addressing the research focus of the participants teaching in ALC classrooms.

The qualitative data analysis process ensured that similarities and differences across the data set could emerge, something vitally important to classrooms that are being used by a variety of faculty across disciplines.

Member Checking

Action research is inherently cyclical and aligns with member checking techniques described in the literature (Bloor, 1983; Bradshaw, 2001; Emerson & Pollner, 1988; Sandelowski, 1993). At each consultation, I reviewed previous data with participants to clarify any points and gain deeper qualitative understanding about the Active Learning Classroom technology. Participants were invited to review their survey during the consultations. Consultation transcriptions created by a third-party service were also provided to participants in order to ensure that the collected data was representative of their statements. Participants were then invited to impart additional or corrective statements into the data. No participant replied with modifications or addendums.

Methodological and Data Limitations

This study would have benefited from a geospatial analysis of the movement of the instructor in the Active Learning Classroom. The instructor's position in the learning space may dictate what tools they used, meaning that those who roamed actively around the space may utilize a different portfolio of tools compared to those who remained situated at the lectern podium. This study also solely examined instructor use of Active

Learning Classroom technology and did not focus on student use of technology for learning outcomes. Given the dynamic nature of the classrooms, understanding the student interplay with and influence on instructors' use of technology is essential.

Positionality of the Researcher

The role of the researcher is important to the design of qualitative research due to the collaborative nature implicit in action research methodology. Positionality, "describes an individual's world-view and the position they have chosen to adopt in relation to a specific research task" (Holmes, n.d., p. 2). As a faculty developer, education technologist, and higher education practitioner, my views deeply shaped the direction of the study. The positionality provided affordances and limitations in this scholarship arena and through a reflexive process as a scholar, I engaged with those aspects implicit to qualitative research.

Three major views guided me to this research and specifically shaped this study, the first is my commitment to improving teaching, a skillset that is intricately delicate, deeply personal and taxing. This view has been shaped by years of supporting faculty and students as an administrator in higher education. The second underlying view that shaped this study is my long-standing dedication to addressing major challenges in the professional work environment by implementing technology solutions that make the experiences more efficient. My personal and professional experiences have helped me to develop a technological expertise in diagnosing, troubleshooting, and improving practice with technology. The third view that underwrote this study related to a deep value that research should be a process, not an extraction of data. I feel that research participants provide evidence and data to others and that as a result, the process of conducting research should be as positive and forward looking as possible, specifically when it's aligned with professional development. After conducting research and evaluation projects for many years, I have developed a deep commitment towards structuring my educational research process in collaborative way between the researcher and the participants. That is, I felt conducting qualitative research must address the participants needs, not simply meet the criteria of my own research agenda. These three underlying principles helped establish, define, and refine this research project so data could be collected jointly through participation and engagement such that participant's teaching practices and educational technology practices were more aligned and possibly improved.

The role of research and my positionality as a graduate student, practitioner, white male, engaging in scholarship allowed me to deeply reflect on my identity as I was intimately involved not only in the analysis, but collaborative gathering of data with the participants. I engaged in an ongoing and personal reflexive process in order to recognize, understand, and become transparent with my own biases and limitations as a scholar (Bourke, 2014). The guiding principles above, led me to investigate qualitative research methodologies to address my research questions. I was guided to and inspired by action research methods as the as a data collection process.

However, these principles elicited several biases and limitations to the study that I needed to address. For this study to be effective, I needed to negotiate access to the instructors and research site. I needed to be an insider, one who the participants could trust as an expert in educational technology and faculty development and as a co-collaborator with regards to the action research methodology. My training in educational research and higher education broadly helped me to understand and develop a solid foundation in research design with expertise in both qualitative and quantitative methodologies. Furthermore, my training and practitioner experience across the academy provided me with the skill sets necessary to conduct program assessment and evaluation. However, with my deep, multifaceted involvement in the research site, I was keenly aware of potential challenges that this fostered.

As an information technology professional, my years of experience working in corporate information technology allowed me to understand how hardware, software, and people interface in real-world contexts. Similarly, I am industry certified in ITIL (Information Technology Infrastructure Library) and thus qualified to align technology strategies with organizational objectives to meet client needs. These experiences allowed me to navigate and understand the classroom support infrastructure from a break/fix, service, upgrade, and asset depreciation aspect. Importantly, understanding this aspect of the technology allowed me to negotiate access into the learning space for the research.

During the research, I held a professional role at the university's center for teaching which helped me gain legitimacy and understanding about the classroom spaces from a pedagogical support perspective. Holding the role as both a faculty developer and a researcher made it difficult to critically examine the influence that I had between my professional role and my scholarly role as a doctoral candidate. As a faculty developer and graduate student, I conducted a pilot study on faculty's use of technology in ALCs and was acutely aware of the faculty experience transitioning to these spaces based on the prior pedagogical support I provided faculty through my role. As a faculty developer, I was intimately familiar with ALCs, student-centered teaching, constructivist pedagogies, and active learning strategies. Over the two academic years, I supported faculty who were redesigning courses to focus on student centered-teaching and learning. I also supported two year-long faculty fellowships at the university to assist faculty transitioning to Active Learning Classrooms. This research study was a natural extension of my professional and educational background. These skill sets and experiences prepared me to be a reflexive scholar-practitioner, allowing me to apply action research methodology to faculty development and education technology contexts.

As I engaged in the reflexive process about my various roles, I recognized my agency as a scholar-practitioner and the access I was given to conduct this study. The split identity I held as being both a professional and a student continued to impact the critical reflection of my scholarship whilst maintaining a professional identity simultaneously. I expected that my professional identity would aid me in connecting with faculty instructing in ALCs, especially those who were newer to the environment. At the same time, I confronted the internal struggle of deeply connecting with older and very experienced faculty who had many years of prior experience in the learning space. I felt that as a white male with professional technology support experience, I was welcomed to the ALCs in a way others without my background might not be. Specifically, my background as a technologist and faculty developer legitimized my identity as an expert able to conduct this research. At the same time, I felt that my positionality as a young scholar, interested in teaching and learning brought fresh perspectives to the learning space, but my limited hands-on experience teaching in the ALCs left me wondering if I could adequately address all of the pedagogical concerns expressed by faculty during the action research study.

Throughout the research phases, I confronted these expectations and consulted authentically from my experience as an education technologist and faculty developer. During the process, I noticed that instructors who were newer to the ALC gravitated towards the experiential learning aspects that involved classroom technology and instructors with more experience discussed deeper aspects of pedagogy at a more refined level. I also believe that my experiences as a young scholar and practitioner in the field providing a short-term study with limited experience in the space primed me to focus on the newest instructors first. While I was intrigued by the deeper pedagogical discussions and found them helpful for the research, I felt limited in my scope to be able to consult with them more deeply while remaining focused on the technology of the classroom.

Similarly, my positionality placed me as an "insider" in the research process, one who understood or held knowledge about the learning environment and its technology, but I did not necessarily possess any greater knowledge than the participants themselves. Albeit the research design intentionally facilitated a learning process whereby my knowledge was shared or co-constructed alongside the participants. However, while this is both an asset to the action research methodology, it relied on a level of trust and expertise that deeply impacted the rapport I had with participants because it relied on my expertise in faculty development, and my expertise as a graduate student in education technology. Negotiating my professional identity and scholarship allowed me to work as an insider for the context of the data collection and data analysis.

However, I was at the same time, an outsider in the research process. As an outsider, I was not a fellow instructor responsible for leading a class, educating students, and navigating a technology-rich ALC learning space. I drew on my insider status as a practitioner to leverage my understanding of larger institutional contexts, classroom technology specifics, and a series of prior-experiences supporting instructors in the space. I relied on my understanding of student learning and faculty support, instead of first-hand knowledge of teaching in the spaces. However, not having an instructional responsibility in the classroom left me compensating for current teaching experience, especially with regards to instructors with many years of prior experience in ALC environments.

Issues of positionality remained active throughout my data collection process as I navigated the complexities of providing technological support through experiential learning methods. As both an insider at the university and practitioner in the field, the experience and expertise proved helpful, however, as a researcher, with fewer years of experience than some participants and no current teaching capacity, my positionality allowed me to be a recipient for deeper pedagogical discussions.

However, the subjectivity and proximity to the research site required me to draw clear boundaries between my professional role and my role as a research. "Positionality requires that both acknowledgement and allowance is made by the researcher to locate their views, values and beliefs in relation to the research process and the research output" (Holmes, n.d., p. 5). During the course of the study, participants were not included in the work I did for the center for teaching. Consultations, programming, or other requests made by participants were anonymously triaged to other colleagues in order to prevent a cross-over of responsibilities between the research and my professional responsibilities. Additionally, from a data analysis perspective, I was privy to institutional contexts and details that I was cognizant of. For example, I had prior understanding colleges' administrative adoption of particular hardware, which impacted the participants in my study. While this provided context and understanding, this type of knowledge was not necessarily replicable by other researchers.

Overall, as both an insider and an outsider, negotiating my positionality, I was allowed to engage with participants in a shared collaborative data producing process. As an action researcher conducting a study on this domain, I carefully negotiated my role and my positionality as a scholar and practitioner. The process required me to modify my professional role in the center for teaching while simultaneously impacting my approach and insights to the field of faculty development.

Having taken the time to reflect on my experiences as a scholar-practitioner, I am mindful of the reflexive process, the delicate balance of working with and alongside participants in a way that deeply shapes the data collection process and results. As a researcher who engaged in action research with instructors, my positionality is a critical and vital element of the research process. The affordances and limitations of my positionality are reflected in the design, collection, and analysis of this data. Due to this implicitly and subjectivity of results, the reflexive process helped me identify, confront, and mitigate, where possible any challenges to the research.

Conclusion

This qualitative research study was designed to mirror a faculty development program using action research methods and Kolb's ELT framework to address three research questions pertaining to technology adoption and barriers to adoption in ALCs. I recruited 13 instructors from across disciplines assigned to teach in these spaces. The complete and rich data set was examined and interpreted reflexively through my own positionality as I examined, analyzed and interpreted the combined data from surveys, observations, and consultations. The results of this research are discussed in the subsequent chapter.

CHAPTER 5

RESULTS

Introduction

This chapter is comprised of three major sections, each one addressing a major research question. In the first section, I discuss how Active Learning Classroom technology is used by instructors; in the second, the barriers and adoption factors pertaining to classroom technology; and, in the third section, faculty case study vignettes pertaining to the action research and experiential learning components of the study.

Section I: Technology Use

This study was guided by the following research question: **How and for what purposes do faculty use technology in the ALC?** For the purposes of this study, technology is defined as hardware and software unique to and physically available in the university's Active Learning Classrooms. Numerous other technologies, including online applications and Learning Management Systems (LMS), were used in the ALC space and referenced frequently by participants. However, these tools were eliminated from the study as they are available to all instructors at the institution and are not unique to the Active Learning Classroom environment. Instead, this research focuses on examining the twenty-six technology tools whose physical availability is unique to the Active Learning Classroom learning environment.

A combination of classroom observation, surveys, and faculty development consultation data was used to address this research question. Through scholarly thematic analysis, overarching themes emerged from the data that bisect the individual instruments and speak broadly to macro-level findings regarding Active Learning Classroom technology usage. Instructors often set up technology to broadcast to the LCD TVs at the start of class and continued to use instructor-oriented tools during their class, including their own laptop and the podium interface. Microsoft Surface tablets were important, as were whiteboards, particularly for STEM disciplines.

Technology Preference and Classroom Fit

Information about instructor technology preference was gathered because platform orientation was deemed important in a pilot study of new Active Learning Classroom instructors (Wheeler, 2015). Based on that pilot study, Active Learning Classrooms configured with Windows-only hardware or dual-boot Windows-Mac hardware were identified as a source of frustration for instructors who preferred Apple products. A similar source of frustration was a mismatch between the classroom technology and the devices or technologies mandated by an instructor's college or department. In this research study, for example, both the College of Engineering and the College of Nursing required students (and instructors) to purchase particular computer and mobile platforms. When there was a mismatch between classroom orientation and the technology instructors and students preferred -- or were required to use -- there was increased fatigue in using the classroom technology.

In order to understand the classroom-instructor fit, participants were asked to rate their self-identified technology preferences in a survey. Respondents were asked to select all technologies they used regularly, rather than just the one they most preferred. Results are summarized below.

Table 10

Instructor Operating System Preferences

Computer Platform	Frequency	Mobile Platform	Frequency
MAC OS	8	iOS	7
Windows	6	Android	3
Linux	2		
	N=13*		N=10*

*Options are not mutually exclusive, as participants may choose to use a number of platforms.

All instructors selected at least one preferred computer platform. Instructors generally reported a preference for Apple-based computer platforms and mobile operating systems over Windows or Android platforms. One instructor, Brian, said he preferred Linux and adopted both Mac and PC recently. Though many participants preferred Apple-based platforms, during class observations, there were five instructors who used Microsoft Surface tablets that run Windows.

In four out of the five Active Learning Classrooms, the instructor lectern computer was a dual-boot Windows/Mac computer, allowing the instructor to use the operating system they preferred. On the student side, three classrooms included Windows-Only student laptops while only two classrooms had dual-boot Mac/Windows student laptops. (For full details, please see table 2 in the Methods section.) The Active Learning Classroom Tyson used (N11) was the only classroom that was entirely PC-oriented, with both the instructor computer and all student table laptops running only

Windows. Where there was a discrepancy between instructor technology preference and classroom orientation, many instructors resolved the issue by bringing their personal laptops and connecting them to the podium interface directly which addressed their needs.

Technology Tool Importance

Participants also took a pre-survey asking them to rate the importance of twenty-six technology tools available to instructors and students in the Active Learning Classrooms (*n=13*). The survey included a list of tools, each with a photo to help participants identify the tool in the classroom if they did not recognize the name. (For a list of these tools, refer to the Methods section). Descriptions of the tools were not included in order to prevent skewing the results. The data gathered from the pre-survey questions is reported below. Results are also summarized in the figure below, with tools listed from those rated most to least important.

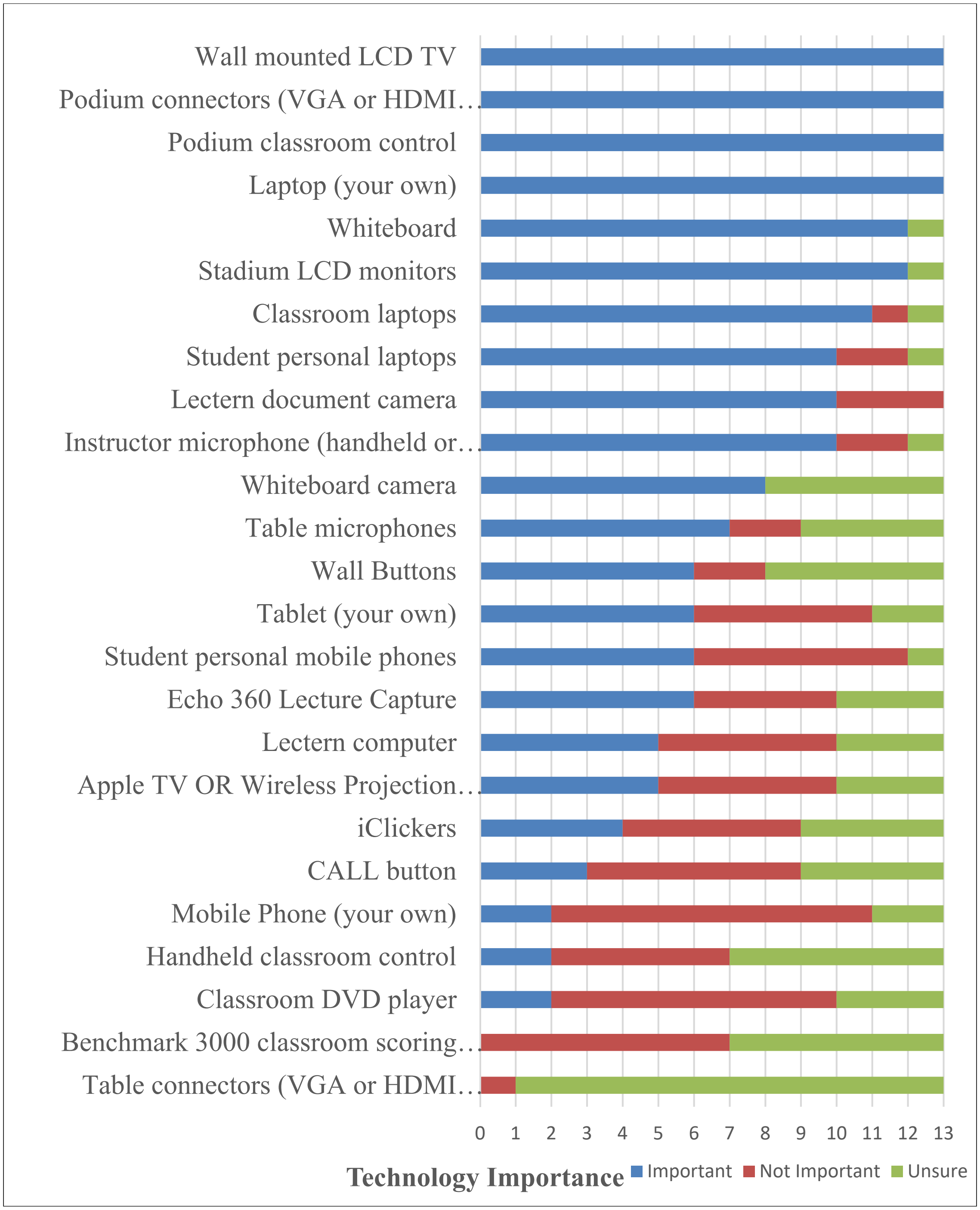


Figure 7 Technology Importance for Instructors

Note: Participants rate importance of 25 technology tools available in the Active Learning Classrooms including common Bring-Your-Own-Device items (n=13)

The survey revealed large consensus on which classroom technologies were most important. Tools rated as "Important" facilitate instructor presentation and information flow and are often compatible with traditional classroom environments where the instructor serves as a "sage on the stage." The tools rated as Important by all 13 participants included wall-mounted LCDs, the podium connectors for laptop or other input source connection (e.g. HDMI, VGA), the Crestron podium interface that routes various inputs and sources, and the instructor's personal laptop. Similarly, 12 of the 13 participants rated the whiteboard and stadium LCD monitors as Important. The tools most frequently rated as "Not Important" included instructor mobile phones (n=9), the classroom DVD player (n=8), and the Benchmark Scoring System (n=7). There was a wider variety of responses regarding the whiteboard camera, table microphones, wall buttons, instructor tablets, student phones, Echo360, the lectern computer, Wireless Projection System/Apple TV, iClicker, and CALL Buttons. These last items received a range of Important, Not Important, and Unsure responses.

In some cases, participants marked a tool as "Unsure" because they were unfamiliar with it in general; in other cases, they were not sure how it could be applied to their teaching in particular. The handheld Crestron classroom control was one example of a tool that received a number of "Unsure" or "Not Important" responses for these reasons. Six participants were unsure about the handheld Crestron classroom control, while five found it not to be important. Another tool frequently marked "Unsure" was the Call Button. Four participants said they were unsure about its usefulness, while six participants said the Call Buttons were not important at all. Instructors were most unsure about student table connectors, which allowed three students per table to connect their laptop or other BYOD via an HDMI audio/video wire. Twelve participants said they were unsure about this tool, while one reported that the tool was unimportant.

In addition to rating 25 specific tools, instructors were able to mark "Other" and report additional tools they used in the Active Learning Classroom. Two instructors identified tools pertaining to rapid in-class formative assessment, including IF-AT scratch cards and Socrative. These paper and digital tools provide iClicker like functionality. Other write-in tools included iPeer and NoteFlight (a web-based music notation program). The instructor who wrote in NoteFlight also suggested piano equipment for his music class, and two instructors emphasized the importance of an analog wall-clock for keeping track of time.

Classroom Observations

Each of the 13 participants was observed twice, yielding 26 unique Active Learning Classroom technology observations. These observations include pre-class observation and during-class observation. One instructor arrived late to class, so the pre-class observation for that period is not available.

Pre-class Observations

All instructors engaged in a pre-class setup phase, which frequently involved a setup of the technology they planned to use during the class period. However, one instructor only engaged in setup during one observation, as he was running late to class. Observations began 10 minutes prior to the start of a class in order to capture the instructor's setup process in the Active Learning Classroom. Participants were often juggling multiple tasks such as configuring their devices, greeting students as they walked in, discussing in-class duties with TAs, and distributing grades or other feedback to students prior to the class period. However, there was much less technology testing than expected. This lack of testing was likely due to the fact that these were tech savvy instructors, most of whom were Active Learning Classroom teaching veterans. Three major themes that did emerge from the pre-class activities were classroom configuration, use of multimedia, and hardware setup.

Classroom Configuration

Twelve of the thirteen participants set up at the podium location at the center of the classroom. This setup process most commonly involved plugging in a personal laptop or tablet and pushing the content to all LCD monitors. Often, the content was a PowerPoint presentation. However, there were also notable non-standard classrooms setup configurations that impacted technology use during the class.

For example, music instructor Anderson's setup was more elaborate. In addition to connecting his iClicker base station to his Mac laptop and playing music from his laptop over the HDMI connection, Anderson also brought his own piano keyboard to class and situated it next to the podium. He compared this configuration to his preferred setup in a music classroom, where he would lecture while sitting at a traditional acoustic piano with a document camera positioned adjacent and displaying content to his students. Describing this traditional classroom setup, Anderson said, “I would lecture, sitting at a piano, playing things. So that as I'm talking about them, I'm reinforcing what those concepts are with the sound. [In the Active Learning Classroom] I'm doing that to the extent possible by plugging in an electric keyboard.” However, Anderson ultimately did not end up using the electronic keyboard during the two classroom observations, in part because he said he preferred a true acoustic piano. On a technical level, he said the portable keyboard had shrunken piano keys, which meant that “Whatever muscle memory I've developed playing piano does not apply to [the keyboard] and it really is weird trying to find these notes in a [physical location] that's different.”

Alexis, a theater professor, also had a different classroom configuration during one of her class periods than the majority of the participants. During one observation, she set up at the podium like most of the instructors and then asked students to congregate on one side of the classroom by rolling their chairs into a huddle. Alexis had invited guest playwrights to class to read a play for the entire period, so her intent was to transform the classroom space into a theatre-like experience. Each of the four guest actors sat just in front of the podium, facing the crowd of students who were separated by only a couple of feet creating an intimate environment. During the follow-up consultation, however, Alexis said that this use of the Active Learning Classroom was the exception rather than the rule: “That was a really different class. You saw guests come and sitting and reading a play, so I used no technology really except the clock. That was very unusual, like I'm using technology all the time [in other class periods], so you just happened to be there when it wasn't being used at all." In fact, though, Alexis was still using technology even during that particular classroom observation. She used Echo360 and the instructor microphone to record the performance for the benefit of the actors, who were upper-division students of hers. Since they were volunteering their time to model theater for her lower-level students, Alexis wanted to return the favor by recording the event in case the video might be useful for them in future professional or academic endeavors.

A third instructor, Brian, avoided setting up at the podium entirely. He wrote in his initial survey, "I don't like having students behind me. As such, I have set up in the corner." Brian regrouped students so that there were ten at each table, leaving a vacant 9-student table in a far corner of the classroom that he used as his teaching station. He set it up with a wooden lectern and led the class from this unique vantage point by connecting his Microsoft Surface tablet into one of the three HDMI input wires traditionally available to students at the table. He said, "I realized I didn't have to bring my [HDMI adapter] with me if I just unplugged one of the student laptops." He also said that he found this location more convenient overall: "I personally feel the room's actually a lot easier to control from one of the student tables." By using the Wall Buttons associated with the student table to broadcast his Microsoft Surface display around the room, he was able to bypass the multi-step selection process inherent to the podium interface. While utilizing the student table location meant that he lost access to the stadium LCD monitors, Brian was willing to give up that option for the convenience of his preferred setup. He said, “In terms of every-day speed, the [Wall Buttons] are way faster and way easier [than the podium interface].”

Brian, who was teaching in an Active Learning Classroom for the second time, also adopted this location for classroom management reasons. He noted that, given the configuration of the room, an instructor standing at the podium would have their back to some of the students. Brian said that was especially an issue for him because, in his first semester in an Active Learning Classroom, “[he] ended up having one of my weaker teams end up being behind me.” In this, his second semester, he decided to change that, saying, “I'll just transfer [to the student table] and have no one behind me, and I have a whiteboard back. All of which are good things.” Indeed, Brian’s unique location provided him with an opportunity to face all of his students, as well as providing a simplified set of wall-buttons available to broadcast his display after he used the student-table laptop connector to attach to his Microsoft Surface. He was aware that this location limited his access to technology hardware, but felt comfortable visiting the podium occasionally, as discussed later.

Multimedia Use

Several instructors activated audio and video during the pre-class phase. Their use of multimedia was intended variously as a pleasant way to help students transition into the classroom environment, a means of connecting to daily content and to larger course themes, and a subtle demonstration of instructor personality. Anderson, for example, displayed a PowerPoint presentation with an embedded music file to all screens in the classroom. The classical music, which referenced a musical theory concept from a prior class, played softly in the background as students arrived. Once the class period started, Anderson paused the music and connected what the students had heard to the day's lesson as well as to a prior lesson in music theory. Alexis used pre-class background music in a similar fashion: her course covered American media icons, and she played the song "American Woman" to connect the theme of the course to the day's topic on digital media and culture.

Similarly, Daniel plugged in his iPhone via the auxiliary headphone jack at the podium interface and used it to play background music as students entered the classroom. He said he got the idea during a conversation with a consultant at the University's Teaching & Learning Center. As an engineer, he had not previously thought about how audio could play a role in his class. However, after the conversation about strategies for teaching in an Active Learning Classroom, he decided to use it as a calming welcome to help students settle into his 8:30AM class. He said, "I get here early like, say, 8:15AM and I hook this [iPhone] up and I just play fairly mellow stuff as they come in." Along with the music, he displayed an introductory slide that provided a basic agenda and directed teams to the online problem sets hosted on the LMS. Music was also used to signal the end of class, as well. Daniel said, "You know that song, 'Na-na-na, hey, hey, hey, goodbye?' That's my good vibes song. I give them like a five-minute warning... I [play the song], that's their signal that today is over and they've got to leave. It got a big laugh [from the students] the first week, now, it's just accepted."

Rather than music, Lindsay preferred to play videos as her students arrived and got settled. For example, during one pre-class observation Lindsay played a YouTube video promoting the University's Outdoor Club activities, which broadly connected to the sustainability and eco-friendly practices covered in her class. Lindsay described this use of pre-class multimedia as follows:

> I intend, whenever I can, to have a video playing as students enter the classroom and have it related to class in some way… For example, in my fall [ALC] class, we have a unit on forest ecology... Really, really good for videos. The beginning of class, when we're in [that unit], there'll be a video playing of [people doing] meditation in [the] forest or just showing forest scenes and music or a clip from a documentary showing people tree-climbing and doing forest ecology research… It sets a tone and it gets them grounded in the topic before I even talk.

Lindsay displayed these videos on multiple monitors in the pre-class period, and their visuals and soothing sounds created a calm tone that helped students transition into the classroom environment. Similar to Anderson, Lindsay's use of multimedia was also specifically intended to make connections to the day's topic and larger course objectives.

Hardware Setup

Active Learning Classroom hardware setup occurred during the pre-class observation period. While most participants expressed comfort with using the Active Learning Classroom technology, every instructor still brought their own laptop or Surface

Tablet to at least one of their two observations. In part, this was because of the relative ease with which instructors could connect their personal devices to the instructor podium. As Chris pointed out when asked about his preference for using a personal laptop as opposed to the lectern computer, “It's so easy to put it in my own laptop. I don't see any reason not to.” Some instructors also had a technology preference that did not match the orientation of the classroom, as described previously. And sometimes, as in the case of the Microsoft Surface tablet utilized by five STEM instructors, the personal devices instructors brought provided additional functionality. For example, Brian, Christi, Mitch, Lindsay, and Hans used their Surface tablets to provide mobile whiteboard capabilities, “hand written” problem-solved examples, inking abilities, and student modeling.

Teaching assistants also played a role in setting up technology during Hans’s first observation. During the pre-class time, he quickly demonstrated to two TAs the various technologies in the classroom. Hans provided an overview of the lectern podium touch control system that operated much of the classroom’s technology, and walked them through the various input and output features. He pulled up the Echo360 camera display on the lectern podium control, and briefly demonstrated the document camera features to TAs by placing a marble on the display piece.

Another frequent hardware setup process involved microphones. Six instructors (Marie, Daniel, Lindsay, Hans, Mitch, and Anderson) activated the instructor microphone during the pre-class phase. Five of the instructors picked up the device from the instructor podium and attached the lavelier mic to use in class, while one (Marie) appeared uncomfortable with clipping on the microphone. When asked about this during consultation, Marie said, “I hate my instructor microphone [it’s a] sexist microphone, because [the base has] got to be stuck in a pocket and ladies often don't have pockets.” Despite preferring a hand-held microphone, Marie did still pick up the lavelier mic occasionally during class and speak into it, especially to quickly gather the attention of the students while they were working in groups.

Class Observations

All thirteen ALC instructors taught in one of five Active Learning Classrooms. Classroom observations occurred behind the instructor’s podium in order to maximize the view of instructor’s use of technology, with the exception of observations in classes conducted by Brian, who taught in ALC room 4, used a non-standard location for his teaching. As such, the classroom observation location moved to accommodate this teaching style. For a detailed description, see Active Learning Classroom 4 shown in Figure 2 in the Methods chapter.

Each participant was observed twice, for the entire duration of their class period. The focus of these observations was instructor use of technology. The major themes that emerged were instructor-centered technology uses and non-instructor locus technology applications where students engaged with technology.

Instructor-centered Technology Use

Active Learning Classrooms are designed to foster student-driven active learning; however, they also provide a number of instructor-centric technologies that support lecture and information broadcast. While all 13 instructors transitioned into student team activities over the course of the class period, eleven faculty began class by utilizing technology to support a more instructor-centered activity. The podium station, located in the middle of the room, served as a command center for launching the class. As an extension of the podium, the stadium LCDs and wall-mounted monitors displayed information from the instructor's personal device or the lectern computer. Likewise, the instructor microphones were used by several instructors to broadcast their voice across the classroom. The instructor-centered configuration of these classroom technologies is captured in this photo, which depicts the central podium and surrounding constellation of LCD TVs.

Figure 8 Instructor-View of an Active Learning Classroom

Podium as Instructor Command Center

Most participants maintained full control of the classroom technology through the instructor podium. This complicated piece of equipment served as the central toggling station in the classroom and could control nearly every technology device in the space. The podium interface facilitated the multi-display functionality of the classroom, allowing instructors to push various sources to the stadium and wall-mounted TVs, including the lectern computer, document camera, DVD player, and personal devices like laptops and tablets. While students could overwrite their local LCD TV, instructors could always take back control of LCD screens from the podium. Instructors could also use the podium to access student table laptops, whiteboards, and any student BYOD connected to the tables, with (or without) student permission. In essence, the technology configuration of the classroom lent itself to instructor control over the classroom space.

Most instructors described the podium as both very useful and fairly easy to use. Lindsay, an experienced Active Learning Classroom instructor, recalled her initial impression of the podium interface: “The first time anyone showed me the interface, I was incredibly impressed. I'm still impressed. It's so user-friendly.” Anderson focused on the podium’s flexibility for managing multiple displays and input sources: “I'm jumping between document camera and PowerPoint on my laptop, or I have audio on my laptop, or the piano keyboard that's electronic can plug into the audio system in the room if I wanted to.” While Alexis commented that sometimes the myriad possibilities meant that the podium “felt like it was a whole smorgasbord of things that I didn't really know,” she cast this feeling in a positive light: “I learn every day. I'm like, ‘Oh, when you touch this, that magical thing happens.’”

Despite the numerous options for configuring the system, most participants felt comfortable using the podium control; however, this did not mean they never experienced issues using the technology. Tim found the podium setup to be “relatively straightforward,” but also said, “I know folks can be intimidated by this.” For example, Chandler, a first time Active Learning Classroom instructor, was not always entirely clear on the functions of the podium. He wrote in his survey that he was “still learning the system” and lacked confidence with the interface. He continued that he “sometimes gets confused on what to press,” especially when he needed to use the podium to interact with the student-table or student personal laptops. This feeling of uncertainty was not unique to the first time Active Learning Classroom instructors, however. Even Tim, who felt relatively comfortable with the interface, admitted that it did not always behave as he expected: “A couple of times...I think something else is [displayed] up there, and then I look around and realize that it's not [displayed].”

In most cases, instructors used the podium controls to broadcast a personal device to the classroom LCD TVs. In 25 of 26 observations, instructors utilized a personal laptop or a Microsoft Surface tablet due to technology preference or the convenience of using a personal device. Tyson, for example, always brought his Mac laptop because, he said, “I'm far more comfortable and confident on the Mac.” Chris used his own laptop because it was already configured to access the content he needed. Prior to class, he curated relevant documents and information for each of his teams on his laptop; then, during class, he went around to each table and connected to the table’s individual wall-mounted monitor so he could display the content locally while collaborating with students. Chandler, on the other hand, was able to use both his own Mac laptop and the

Windows lectern computer because much of the content for his class was hosted on the Learning Management System (Moodle) and could be accessed from any computer with an internet connection. When asked about why he pivoted between computers, he said, “it seemed simple to just use the [lectern computer] that was here...I don’t know why I’m choosing [the lectern PC] over the laptop, there’s no real reason. I’ve gone back and forth.” In this case, part of Chandler’s willingness to move between his Mac and the lectern PC may have been his commitment to open-source software. He said, “I feel like the vast majority of universities really rely on proprietary software and vendor locking ...so in this particular course we’re actually trying to introduce the students to an open source stack that can do just as well [as proprietary software].” Regardless of the degree to which instructors used – or did not use – their personal devices, I observed a strong overall trend to make liberal use of the podium during lecture.

An exception to the rule of controlling the classroom from the instructor podium was Brian, who utilized a student table as his lectern. On the whole, the podium interface functionality was largely replicated at the student-table location. However, while his direct interaction with the podium control was minimal, he or his TAs occasionally went to the podium to perform functions like toggling displays. Even though Brian was positioned at the table location, his use of the TAs meant he was not subject to the same technology limitations as the actual students at the other team tables. He also did not need to worry about an instructor taking over his display, since he had formal control of the classroom.

While Brian's preferred seating arrangement was unique, other instructors occasionally utilized the podium to broadcast student table laptops or other devices connected to the table system. For example, Chandler used this functionality during what he called "share-out moments" when teams reported out their GIS client project work from their personal laptops. Christi also utilized a BYOD camera that was set up at a student table and connected to the HDMI plug typically reserved for connecting student laptops. She used the podium control to select that input display and push it to all of the B-LCD displays. She also used an A team's whiteboard to write during class and opted to broadcast its contents by walking over to the podium, selecting that particular A team's whiteboard, and distributing it to other A-Tables. In all these cases, the podium interface allowed the instructor to retain control over the presentation of information even when utilizing technology at the student tables.

Monitors for Presentation Broadcast

As a visual extension of the instructor podium, the stadium and wall-mounted LCD TVs were key components of instructor technology use in the Active Learning Classroom. The four stadium TVs were positioned above the instructor podium and could only be accessed by the instructor station. Each classroom also had between 7 and 11 wall-mounted LCDs, one associated with each team table in the classroom. Unlike the stadium TVs, the wall-mounted TVs could be controlled either by the instructor or by the student teams; however, many of the inputs could only be controlled at the podium, including the document camera, lectern computer, and DVD player. By design, the configuration of the monitors and inputs privileged instructor control over what was displayed.

While teaching, instructors frequently queued up content from their laptop or tablet and used the podium touch interface to push that source content to displays in the classroom, including the ceiling-mounted stadium displays and the wall-mounted displays at the student tables. Marie, Lindsay, Daniel, Tim, Tyson, and Anderson all used their laptop to project PowerPoint slideshows to all LCD monitors during most of their class. Marie also used the monitors to show the Learning Management System (LMS) from her laptop while discussing assignment rubrics. Daniel used his laptop to pull up a problem set created by the publisher Wiley, and display it to all screens so that his students could work at their tables to solve it. Lindsay used her laptop to provide insights and examples about film projects her students were working on by showing storyboards and scripting templates that students could use to create their own work. In all these cases, the monitors provided a constant feed of instructional content and visual cues during the class period.

Lindsay and Anderson also displayed PowerPoint slides in order to provide structure for their classes. Anderson appreciated the way PowerPoint allowed him to present slides, embed iClicker questions, and access music samples from a single interface. He also used his slide deck outside of the lecture components of class to remind students of general administrative tasks. He said that he frequently included slides that suggested to students how far along they should be in their work, and included an end slide that suggested next steps. Lindsay used slides to pace her class in a similar way. She said, “I generally outline my class using PowerPoint slides even if I'm not lecturing. I pose the [particular] question and then say, ‘work time, focus on this, this, and this.’” In both cases, structuring the class with PowerPoint slides helped students pivot between tasks like lecture, group work, group problem-solving, and in-class quizzes. The multiple monitors (stadium LCDs and wall-mounted LCDs) amplified the effect of this strategy by making the information available on all the televisions throughout the room.

In addition to pushing the same content to all the stadium and wall-mounted monitors, instructors with previous experience in Active Learning Classrooms also projected multiple sources at once. For example, Christi posed physics-related questions on one set of displays and provided additional context or supplemental material on the other displays for students to pivot between while problem solving. Anderson and Mitch employed a similar system: their Mac laptops presented a PowerPoint to the Stadium LCDs and half of the wall-mounted LCDs, and the document camera was displayed on the remaining monitors. Anderson’s document camera displayed a printed piece of paper that included student groupings for project work. Tim also presented a piece of paper from the document camera; his paper was a printed agenda. Later, Tim used the document camera to project actual printouts of engineering reports about traffic on A Team’s LCDs. As he called attention to specific statistics on the paper, he zoomed in closely with the document camera. By splitting what the LCD displays were showing, these instructors were able to showcase both general content and provide a specific example on which students could focus their attention.

Instructors also used the wall-mounted LCDs to push content to individual groups. During Chris's class, teams of students worked on a problem-solving assignment about cancer research, and the teams worked independently at their table without using their TVs. Chris disconnected from the podium station and traveled with his Mac to each table. There he used an adapter to connect his Mac to the HDMI plug at the student table and then used his laptop to pull up documents and research articles relevant to each group. As a coach, he discussed these articles with the team for about five minutes, and then, he moved to the next team's table and repeated the process.

It is important to clarify that, even though the monitors were often used to present instructor content, instructors also used the monitors and their class time for a range of learning activities beyond lecturing. For example, Chris's course centered around problem-solving, particularly biological problems pertaining to cancer. He frequently connected his laptop to the podium interface and projected to all the wall and stadium displays for short lectures; however, he also said that he consciously tried to keep "presenting" down to 10-15% of the class period because he saw his role as facilitating student work. He elaborated by saying, "They learn from their work. They don't learn from me." Therefore, he spent the majority of the time facilitating teamwork where students collaboratively gathered, compiled, synthesized, and incorporated the latest cancer research into their semester-long projects. Instead of lecturing, Chris spent most of his class time helping student teams engage with each other and the material by "scootching" his chair over to a team table, plugging his laptop into the local team table display, and reviewing information with them. As Chris's example demonstrates, using

Active Learning Classroom technology for instructor presentation does not mean that an instructor is using the technology without active learning in mind.

While instructors usually found that they benefited from the visual element that the stadium and wall-mounted LCDs brought to the classroom, visibility was also central to the two main critiques of the TVs. Specifically, some participants noted that the stadium monitors could be hard for students to see in a large classroom, while the wall-mounted LCDs could be difficult for an instructor to read when the details on the screen were not large enough. Brian reported that his students told him the stadium monitors were very difficult for them to read from across the room, and in response he stopped using the overhead screens for the majority of the class and found workarounds for when he did need to use them. He said, “You've got a handful of seats in my room for which the stadium monitors are convenient. If you're going to put something up there, it needs to be something that they're not reading in detail. I don't mind throwing a question up there and then reading it.” Chandler felt similarly about the TVs in general, though his critique was centered on the wall-mounted LCD displays. He said:

> I don’t like to admit this, but I’m an older guy now, so my eyes … The one thing that I’m noticing is sometimes the displays are small, not just for me, but even when we’re displaying a spreadsheet, or...maybe some code of some sort. Even on the [Wall LCD] screens … we are manipulating [the content] to try to zoom in … and that for me has been a little bit of an issue because I’ve been talking and looking at the screen.

While more complex data may have looked fine at a close viewing distance on a laptop or tablet screen, using the monitors as a method of displaying that content to the larger class sometimes scaled inadequately for both students and instructors.

Tablet as Digital Whiteboard

The Microsoft Surface tablet was adopted by six participants in this study. The volume of the adoption was not coincidental, but rather the result of an innovation effect. All six Surface users were STEM instructors, half of them from the Physics department. Two key instructors, Mitch and Hans, were identified as the earliest adopters, while Christi, Brian, and Lindsay each noted that one of these two individuals inspired their own adoption of the tablet all of these instructors found that the Surface effectively met a key STEM teaching need that they felt the built-in technologies in the Active Learning Classroom did not satisfactorily address: the need for a simple method of working problems and annotating content that could be displayed to all students in real time.

Surface tablets facilitate “digital inking” through a capacitive stylus, and they were able to replicate the problem-solving or annotation functions which instructors might otherwise have performed at a traditional whiteboard (or a chalkboard). Importantly, physical whiteboards in Active Learning Classrooms are positioned in proximity to specific student tables, and the digital whiteboard or annotation features available to instructors are tied to the instructor podium in the middle of the room. Instructors who utilized the Surface were often seeking a compromise between their familiarity with a physical whiteboard and the need to present their work in a way all students could see, even as the instructor travelled around the classroom. The Surface tablets allowed instructors to annotate over their PowerPoint slides and solve mathematical equations by hand as they would at a whiteboard, while also broadcasting the result to the monitors in the Active Learning Classroom.

Brian highlighted this marriage of traditional functionality to a more technologically advanced package when he said, “The nice thing about the Surface is I can use it as essentially a whiteboard... I can use it as a whiteboard, and it saves what I do.” During classroom observation, Brian displayed a slide that contained only the definition of energy as “an ability to do work.” As he talked about various student definitions, he digitally handwrote the definitions on his Surface tablet, which was broadcasting to all displays. This use case is similar to how an instructor would write student responses on a whiteboard. As the class progressed, Brian continued to use his tablet to annotate definitions to conceptual questions. He also solved equations step-by-step using multi-colored virtual inking markers. After Brian’s problem solving-techniques were broadcast from his Surface for students to see, he then asked students to do similar problem-solving at their own whiteboards.

During consultation Brian explained that his slides displayed “problems more than anything. There's not a whole lot of text.” For this reason, he found it much more convenient to use the Surface tablet to both display and annotate his slides. He illustrated how he could annotate on a blank slide and then open up a larger workspace that he could continue annotating. This capability was vital to step-by-step annotations and writing out problems, he said: “The nice thing is you can see it nests them, and I can nest forever.” Each annotation opened a new blank page, and once one annotation was complete, Brian could shrink that annotation window into a tile and open another space. This feature allowed for unlimited annotation space, which was critical because, as Brian put it, “when you're solving a problem, what you really need is the screen before, for the most part.” The nested nature of the Surface interface allowed him to have endless whiteboard space to problem solve, which would be impossible on a traditional whiteboard due to the limits of its size. Furthermore, because all of the steps Brian went through were neatly and digitally stacked, he was able to quickly go back and review them with his students. In contrast, after several steps worked on a traditional whiteboard, he would have had to permanently erase the previous steps and continue solving from the current position.

Other instructors using a Surface tablet also used the touch features or “digital inking” in similar ways. For example, Mitch utilized the Surface to broadcast his PowerPoint content to all displays. After approximately 10 minutes, he handwrote the equation pi=pf on the Surface; then, as he added more variables, he pointed to them on his Surface with his pen and described them verbally. As the problem solving began to advance, he solved a system of equations. The mathematical formulas were written in two colors: the first equation was solved in red ink, the second was solved in blue ink.

Mitch pointed out that, in Physics, “All diagrams are drawn by hand. Any dynamic situation, a student asks you a question, it's all done by hand.” He said that using the Surface tablet allowed him “to have the structure and organization and cleanness that

PowerPoint gives you," with the flexibility of being able to easily annotate the slides. The ability to annotate was key, he said, because:

> If you're teaching a math-based science, a math-based curriculum, it's a much richer teaching experience if you write up [equations]. This is why a lot of math-based courses use chalkboards or blackboards. Why, is because there's something about writing out math. When you're learning math there's something about seeing it written out by hand that's different than if I just pop in a nice computer-generated equation.

By broadcasting his PowerPoint from his tablet, Mitch got "the best of both worlds." With PowerPoint, he said, "You can organize your thoughts in advance, you can be prepped, you can pace yourself, you can have pictures in there, you can have stuff in there." Using the Surface tablet allowed him "to have that plus all of the flexibility and all of the richness that a chalk and a board give you." By projecting from his tablet, he was able to move easily between presenting and annotating.

Christi also broadcast her Surface tablet around the room as she used a stylus to annotate online diagrams and demonstrate the problem-solving aspects of STEM work. She illustrated and described graphics, and annotated a graph that was displayed on all of the LCD TVs. While Christi left the tablet at the main podium station as though it were a laptop, Hans frequently moved around the room with his Surface tablet, which he relied on as his primary device. He brought a laptop to class for iClicker quizzes, but otherwise used his Surface tablet to present PowerPoints, annotate his diagrams, and demonstrate how to solve problems. To pivot between these multiple inputs while still staying mobile, Hans anchored his TAs at the central podium control so they could switch inputs as needed.

Microphones for Instructor Amplification

In addition to the visual uses of technology strongly emphasized by the LCD TVs, instructor microphones were also used by seven participants to broadcast their voices across the classroom. Marie, who never attached the clip-on instructor microphone in the pre-class setup, did pick it up from time to time in order to speak during class. At one point, as teams were presenting from their individual tables to the entire classroom, she also passed her mic to the students so they could broadcast their voices more effectively to the rest of the class. Similarly, Daniel used the instructor microphone to delicately interrupt students after he visited multiple teams. He said, “Once I start talking into this, within a few seconds conversation kind of dies down.” This use of the microphone allowed him to interject specific support to help students solve problems and report back his impressions of what he saw at various tables. He also used the microphone to talk over a YouTube video he showed to the class in order to offer his own comments about the process they were watching.

Since Echo360 captures both video and audio, the use of instructor microphones was also partially linked to the use of Echo360’s lecture capture functionality – as was the case for Lindsay, Hans, and Alexis. Hans, who roamed around the classroom broadcasting from his Surface tablet, used the instructor microphone to evenly distribute his voice as he lectured, to capture those lectures in Echo360, and to communicate with the TAs at the podium control who were responsible for toggling between various input displays such as his tablet and the laptop running his iClicker questions. As Hans visited various student tables and spoke with the students in small teams, his microphone also allowed his calm talking voice to spread around the room when he decided it was time to report out to the entire class. Alexis and Lindsay's goals, on the other hand, were more specialized. Alexis used Echo360 and the instructor microphone to record a play reading given by her upper division students to her lower level students, and Lindsay utilized the microphone with Echo360 specifically to overcome her fear of being recorded. Reflecting about how being recorded had made her nervous in the past, Lindsay said: "one of my professional goals is to not let that actually impact me anymore. Recording things through Echo360 and getting used to that and wearing the mic all the time...is absolutely working in terms of making me less and less affected by the knowledge of being recorded."

In contrast to the instructors who used microphones to amplify their voices or subtly control the classroom environment, other participants described the instructor microphone as an unnecessary technology for their own teaching. Brian thought it was important to model strong vocal projection for students, and both he and Chandler said they spoke loudly enough without the microphone. Brian also wanted to avoid "fussing" or "fiddling" with the microphone during class, especially when the classroom "is not that big and the sound travels fairly well." Outside of recording the play-reading, Alexis also did not feel the need to use the microphone. She said, "I don't need the mic because I was trained for the theater." Chris and Christi both thought that microphones were not needed in an ALC context, but that there were situations in which they could be useful. For example, Christi agreed that lecture recording was a time when the microphone would be necessary.

2. Non-Instructor Technology Locus

As discussed above, the podium control, LCD monitors, and instructor microphone frequently positioned an instructor as the master of ceremonies. However, the key difference between students working in a traditional and an Active Learning Classroom is that ALCs also have many technology-facilitated microenvironments that allow instructors to engage with small groups of students. Overall, the layout of the active learning spaces provided opportunities for instructors to coach, visit, check-in, and work with multiple small groups. In these cases, instructors frequently used the very same potentially instructor-focused technology tools for non-instructor locus activities, something a traditional classroom does not usually allow for.

Lcd Sharing

While many instructors used the TVs to broadcast information, several also allowed input from students in terms of what was displayed on the wall-mounted monitors. For example, Hans pushed a multiple-choice quiz question to all televisions in his class and instructed students to start problem-solving and display the results on their TVs. As groups began to figure out how to project their work from their team table, the content Hans pushed to these wall displays was replaced by the content generated at each team table. However, as the class went on and Hans brought the class back together, he said, “Okay, we [instructor and TAs] are going to steal the screens back” and returned to lecturing on all displays. This example illustrates how instructors and students in an Active Learning Classroom can share the LCDs and transition between who has control over what the screens display.

Lindsay was willing to share control of the LCD monitors even during a lecture portion of her class. While she was broadcasting a PowerPoint about the environmental impact of coffee bean production to all LCD TVs, Table A4 queued up a picture of a coffee bean from the web from one of the student laptops and it suddenly appeared on their team table monitor so that the rest of the class could see it. Lindsay paused in her lecture and enthusiastically acknowledged it to the class: “Hey, you see how to project to your screen, that’s great.” About 15 minutes later, as Lindsay moved on to presenting about world population, the same table queued up a real-time global population ticker. Lindsay again acknowledged the contribution and pointed to the table’s screen as she lectured, subtly encouraging students to take ownership of their LCD monitors in concert with the class topic.

Alexis also practiced LCD control as a two-way street. Initially, her class setup consisted of broadcasting her laptop display to all TVs and playing music. As the lecture portion of the class wound down and students began working in teams, a Google document appeared on Table A7’s wall-mounted LCD. It was visible to others, and Alexis noticed it and commented about it. Alexis then moved from table to table during this activity, and when she arrived at A7’s table, she looked at the screen before engaging in a conversation with students about their topic. Seeing the student content pushed to the team monitor gave Alexis a point of reference from which to begin engaging with the group.

Hans began class by showing his laptop computer quiz on all monitors, but then suggested that students take over the local displays. As a result, a portion of the class replaced the quiz with their own local content. However, the quiz persisted on the stadium LCDs and on any group table that did not toggle their laptop technology. Later in the class period, Hans looked at an equation written on the whiteboard by students at Table B5, as they opted not to solve the equation on their laptops. Since the quiz was still located on the screen, Hans walked over to their whiteboard and compared their equation to the quiz question. The technology configuration in the Active Learning Classroom facilitated the development of this collaborative microenvironment because the instructor was able to engage with the student team in their space, an interaction which the traditional setup of lecture classrooms does not encourage.

The ability to take control of what was displayed on the wall-mounted monitors also allowed team tables to show their progress to the instructor and to the entire class. At various points in his class, Mitch asked students to report about their learning by using the A/B wall used buttons near their table to push their work to other LCD displays around the classroom. Mitch also made a point of preserving student control over what content was pushed where, and when. He said, “I always believe if they are doing the presentation, they push the buttons…. It's all about giving them the control. If it's their presentation, even if I could go over, my belief is they should push the buttons.” Mitch’s strong belief in the importance of student control of their classroom technology mirrored his epistemological orientation towards guiding students to solve real-world biological problems. In the same way that students were responsible for taking active part in the problem-solving process, the wall buttons allowed students to take ownership of the learning process by making their own decisions about how and when to display their content.

Chris also used technology to foster a strong focus on student-centered teaching. During his first consultation, Chris described how students quickly figured out how to use their wall buttons to display content from their laptop or whiteboard on various wall-mounted LCD TVs. He noted the alternative (instructor-centered) method of queuing up student LCD displays from the podium, and suggested that it was actually more difficult: “I'm more likely to get that wrong than they are to get the button pushed wrong.” Therefore, allowing the students to take control was also a pragmatic choice that lowered the likelihood of failure or “bumps.” In practice, though, asking students to simultaneously push content to their own LCD displays did not always work seamlessly. Chris said that, as students started pushing various displays around the classroom, the student teams begin to “step on each other” technologically speaking. Elaborating, he said, “If it's set so that the displays go to all displays, then one group will be up trying to do something, and another group will push their button, and all of a sudden the room will shift.” Even though in-class execution of technology-sharing was not always seamless, however, Chris still considered it worthwhile to maintain shared control of the technology in order to promote student agency.

Whiteboard Sharing

Where the LCD TVs were the primary device for broadcast, whiteboards were the primary problem-solving, ideation, and collaboration tool in the classroom. As Mitch said, “It's about flexibility...the whiteboards give you flexibility.” He described how student questions and ideas were quickly brought from the table discussion and articulated on the whiteboard, where it was possible for the team, the instructor, and the rest of the class to see. In most cases, the whiteboards were used for problem-solving in STEM classes. For example, students spent most of their time in Christi’s upper-level class doing physics problem sets while she visited team tables to see their progress. At the end of the class, she asked individuals at the whiteboard to quickly report back their solutions in order to demonstrate that they had completed the problems and to answer any questions. Whiteboards allowed students to build their solutions, diagram out portions of the problem, and problem-solve the equations in a highly visibly way that allowed instructors to compare solutions across groups. Non-STEM classes rarely utilized the whiteboards though when they did it was for concept mapping or for letting students brainstorm or project manage.

During her consultation, Lindsay stated that student whiteboards were essential for brainstorming and mind-mapping activities. For her lesson on sustainability, for example, student teams used their whiteboard to brainstorm about their ecological footprint after taking part in activities intended to orient them to the complexities of something frequently taken for granted: how coffee gets from its source to the cup. As part of the brainstorming, students were each handed a coffee bean. They chewed it at their table, wrote a reflection about "what they thought about the bean," and viewed information on their laptops about the coffee bean industry. Students then used whiteboard markers to build and connect concepts pertaining to coffee farming, production, refinement, and distribution -- particularly its ecological impact on the world. During this time, Lindsay went from table to table, asked for candid insights from students, looked at their brainstorming map, and offered her own comments while they worked.

Similarly, Hans traveled the room, checked in with various teams, looked at their whiteboards, and talked with students about their ideas. As he visited teams who were working on the problems displayed on their LCD monitors, Hans quietly used a whiteboard marker and added to their work on the whiteboard, occasionally taking a step back to view the initial equation parameters on his own PowerPoint slides. Sharing the whiteboards in this way allowed Hans to take a student-centered approach to gauging a team's progress as they advanced to the next phase of their problem-solving activity. The whiteboards catalyzed the microenvironment where teams worked together and allowed instructors to seamlessly step in, offer some customized pedagogical assistance, and move onto the next group of students without taking control of the group.

Brian also found whiteboards particularly helpful for gauging student progress. The focus in his Physics class was helping students connect basic concepts and definitions with authentic problems, and the whiteboards allowed him to quickly see how many student teams were getting to their solution. He said, "[I] can just scan around [the classroom] quickly and say, "okay [that student table], they're making headway [and this student table], they're stuck." Brian noted that using the whiteboard for collaborative problem-solving was a learned behavior for students, and conditioning them to do so took time. Brian felt that students arrived in his class unfamiliar with the learning environment of an Active Learning Classroom, which challenged students to engage actively rather than listen passively. Though the whiteboard technology was familiar -- just the board and accompanying markers -- Brian found that students were not used to being asked to engage with the whiteboards themselves in order to solve problems, since writing on the board was an activity usually reserved for the instructor in a traditional classroom. But, he concluded, "Teaching [students] to get up and go to the whiteboards was a habit that was worth teaching them. It took some training to get them to do it, but now they're pretty good at it." Brian felt that student engagement with the whiteboards was essential for learning physics. In particular, student use of the whiteboards helped him to achieve a hybrid lab/class environment where students engaged with content material and physics experiments in one place, which allowed Brian to cover multiple aspects of physics education simultaneously.

While Brian (a new TBL instructor) trained the students to use the whiteboards for physics problems, Mitch (a very experienced TBL instructor who taught a different section of the same course) took a more laissez-faire approach. Towards the end of his first class observation, he simply said, "Okay, there are whiteboards, feel free to use them" and students quickly got up and problem-solved at their table while Mitch watched. This contrast between Brian's approach to student whiteboard use and Mitch's could be attributed to a difference in Active Learning Classroom experience and teaching style. However, despite the differing approaches in training their students, both instructors used the whiteboards similarly to facilitate student problem-solving. During his second class observation, Mitch continuously rotated table-to-table, discussing and assisting students with their problem-solving. The whiteboards allowed him to quickly engage with student teams to see what they were doing, and he often offered assistance when needed. He described the whiteboard problem-solving as very exciting and engaging way for him to witness their learning.

Chris, a veteran Active Learning Classroom instructor, never directed students to use the whiteboard at all. Instead, as students worked on their cancer research project, they naturally gravitated towards the whiteboards themselves. In Chris's teaching, a semester-long project dominated the class and teams of students worked on it together for much of the semester. This extended focus on student-directed problem-solving led students to more easily own and take advantage of their microenvironment, including leveraging the whiteboards for ideation and collaboration. As in the cases of Hans and Brian, students ultimately used the whiteboards for brainstorming and complex problem-solving, regardless of the amount of coaching they required to begin doing so. Similar to Lindsay, Hans, and Brian, Chris circulated around the room and used the student work on the whiteboard as a starting point in conversations with individual teams. For example, as he approached a team table, he began by saying, "What a nice diagram you have there, guys." Chris then proceeded to review that diagram with the group and ask questions designed to get students to further engage with and modify their work.

Daniel and Chandler's students also used the whiteboards for diagramming. In Daniel's Engineering class, the goal was "taking a word problem that describes a chemical process and making a flow sheet out of it." This realistic praxis task asks students to engage with written paragraphs that detail real-world engineering challenges. From there, students derive the essential chemical equations or mathematical equations that need to be resolved. Daniel said that diagramming the word problem on the whiteboard was vital because students could "look at the pictorial representation" and derive various mathematical equations from the picture. Similarly, Chandler used whiteboards with students to diagram database-related concepts. As student teams developed web-based GIS programs for clients, they each "did a wire frame diagram" that helped them envision the final software product. Each of the team tables sketched their diagram for approximately 40 minutes while Chandler checked in with the various teams. In both cases, whiteboards allowed small groups of students to express their ideas about real-world challenges in such a way that both student teams and instructors could engage with the content.

In addition to creating their own diagrams, Chandler's teams rotated around and visited each other's whiteboard diagrams for approximately half an hour. Particular diagrams were also called up and displayed on the LCD displays by way of the whiteboard camera, allowing the entire class to focus on that group's work. Similarly, Alexis made use of the whiteboard cameras when her students were tasked with discussing a documentary they had watched and then writing a brief summary of their group's discussion on their team table's whiteboard. After the groups had synthesized their thoughts, Alexis worked with her Teaching Assistants to pull up each of the whiteboard cameras in turn and distribute the images to all LCDs. As each team's whiteboard was displayed, she would look to the group from her position and ask what came out of their discussions. In both of these cases, whiteboards were used to showcase unique aspects of each group's work for the larger class. The instructors fostered student use and control of whiteboards and LCDs, and even instructor-centric classroom technologies facilitated student-centric learning by highlighting unique components that emerged during the student-centered activities.

While he did not make use of the whiteboard cameras, Tim did use the whiteboards for reporting out group work. Groups in his highway engineering class used the whiteboards to create various proposals for a safety problem and then presented their solutions to the rest of the class. Tim found that whiteboards were very convenient for this purpose because they were evenly spaced throughout the classroom and provided an easily available and flexible tool for making problem-solving visible to the entire class. Because teams often approached the problems from various angles, the visuals provided by the whiteboards helped Tim to make meaningful connections between different yet interrelated parts of the larger topic discussed in class. Like Chandler and Alexis, Tim fostered presentation skills by asking students to report out on their work, then recognized their efforts by highlighting and connecting the ideas of each group.

Marie used the whiteboards slightly differently during her class. Instead of having each team report out from their whiteboards, she had her TAs adopt a single whiteboard as a central reporting station. She and a TA then alternated as the class scribe, synthesizing verbal reports from various team tables. After student teams worked to research a famous nurse in history, Marie had each of them report out their findings to the class while the TA compiled notes onto a single whiteboard. By jointly reporting out into one unified whiteboard, the class-wide products were developed into a knowledge base about figures in nursing history to which all teams equally contributed. This kind of unified reporting on an instructor co-opted whiteboard was essential to Brian's teaching as well. After working on physics problems at their team tables, Brian would sometimes ask students to participate in a "metacognitive" exercise that required them to come to the student table Brian had adopted as his instructional position and explain why they had made the problem-solving choices that they did. By the end of class, Brian would have a list of all problem-solving choices made by the various teams that he could discuss. Importantly, students shared with the entire class the process of how they got to their solution, as opposed to just the answer. Brian said that "students are responding very well" to this pedagogical technique, and that he planned to continue using this strategy throughout his teaching.

There were, however, several critiques of the whiteboard as a teaching and technological tool in the Active Learning Classroom. Christi, for example, found the board's size to be simply insufficient for the volume of problem-solving she had her students undertake. She said, "[I] grew up lecturing on blackboards, now whiteboards, and doing a lot of writing. [I'm] writing equations and solving equations, [and] making drawings." Having used the large whiteboards frequently available in traditional lecture classrooms, she felt that the many smaller boards located at student tables were not large enough to accommodate the written equations in her class. In addition to the size of the whiteboard, three instructors were also frustrated by the lack of whiteboard surface area captured by the whiteboard camera. Daniel said, “One time, I really wanted to work off of an example that [Table] A4 was doing. They had a really nice picture on their board that I wanted to use. I hit the whiteboard cam and what they had done, half of it was out of the range of the camera.” Christi similarly found that students often wrote beyond the whiteboard camera’s field of vision, and it became a problem when she wanted to project their whiteboards to the class. Though, Christi noted that her students also developed a clever way to circumvent the issue: “[the students] ended up marking out the corners [where the camera captures].” Lindsay, in contrast, ultimately felt that the camera was more trouble than it was worth when she could more easily point to whiteboards around the room. “I don't generally utilize the camera too much,” she said. “It's often dark and hard to read. Often, when we'll do brainstorming, students can see all the boards anyway. We'll just talk it out and point, "Oh, I see over there that you've got….” While instructors could have ambivalent or even negative feelings about the whiteboard cameras, however, they generally seemed positively inclined towards the whiteboards themselves -- particularly for problem solving activities, team collaboration or diagramming, and class-wide reporting.

Device-facilitated Participation

In several cases, instructors used classroom or personal devices to facilitate student participation. For example, three instructors used iClickers frequently in class to encourage their students to participate in discussion. One of them, Lindsay, used iClickers because she wanted “the team members to be accountable for being [in class].” She made it clear to students that the iClicker activities served an attendance purpose; however, she did also embed conceptual and opinion-based questions related to the class in order to gauge overall understanding of and opinions about particular topics. For instance, she polled the class to find out whether they agreed or disagreed with the idea of human-made climate change. Based on the participants’ responses, she then made adjustments to her discussion of the topic to cater specifically to those who agreed, disagreed, and did not know.

Hans also used iClickers to encourage student participation that would allow him to adjust his lecture and other class activities accordingly. He said, “without using some kind of personal response devices, I would have less of a clue as to whether they are understanding certain concepts, so I am getting instantaneous feedback.” By using the iClicker questions to get feedback on how well students understood the day’s concepts, Hans was better equipped to decide on the fly whether he needed to spend more time on a topic or if the class was ready to move on. He also expressed that using a “variety of technology” as opposed to the same type “helps the engagement” part of class.

Both Lindsay and Anderson struggled with how best to incorporate iClicker questions, always striving to find new or better ways to use them to facilitate participation. Lindsay was initially unhappy with her use of iClicker questions, but said that her efforts to make them more substantive were paying off: “I feel my questions are getting better, they're getting to a place where they're really engaging in conversation.”

Anderson likewise struggled with finding the best way to conduct iClicker sessions. He incorporated four brief iClicker questions at the very beginning of his class to check conceptual understanding from the previous session, then broadcast a summary of the answers to all students in order to guide the subsequent instructor-led discussion. Anderson said, there are “really just four [separate] individual reading comprehension questions. I struggle with that, whether that's really the best way to do it.” Like the other instructors using iClickers, Anderson used the questions for a basic comprehension check that then shaped his instruction; however, like Lindsay, he also wanted to optimize the tool’s engagement potential in a way that would encourage students to actively apply what they had learned.

Rather than iClickers, Marie used iPads to foster participation and group learning by having students record and reflect on their class activities. She said, “One of the projects, they have to interview an RN, and so I have somebody film them.” This activity allowed students to utilize their BYOD technology and actively participate by enacting and filming their praxis-oriented learning. Marie also talked about how students used the iPads to record and debrief after clinical simulations. She elaborated, “you only have a couple people in the simulation, then you have some observers, and I always make one of the observers the camera person. They film the simulation, and then the group can watch the whole thing afterwards and play it back and see what they did or what they missed.” In this way, the iPad recording allowed students to enhance their participation by providing a digital record that they could refer back to in order to deepen their analysis of the simulation.

As with Marie's use of iPads, other instructors also asked students to curate knowledge using a variety of personal computing devices. For example, students in Tyson's class were assigned to provide peer feedback on their LinkedIn profiles. Tyson encouraged the students to engage with the assignment using their own laptops or student table laptops. He said, "I could rely on the tech to make them connect with each other. I give them stuff to do at the table so they could be making those connections." This technology application facilitated peer-to-peer participation within the class period.

Cell phone cameras were also used to deepen students' engagement with their work. In the final minutes of class, Daniel encouraged students to take out their cell-phones and photograph relevant course material on the walls and LCD TVs. According to Daniel, this activity helped students participate in the curation of their own knowledge by allowing them to capture those items most important to them from the class. Lindsay encouraged students to use their cell phone cameras to share as well as record their work. During her first observation, she walked around the classroom and captured photos of her students working together on group projects about environmental issues. Then she showed students a slide that provided a variety of social media feeds pertaining to environmentalism and suggested that students upload their own photos of group work to these social media feeds, just as she had started to model. By modeling this particular form of cell phone use, Lindsay encouraged students to use their own photos and social media to participate in a broader conversation about environmentalism.

While numerous technology tools were used in the ALC classroom, not all tools were found to be important to instructors. As noted earlier (Figure 7) tools such as the classroom DVD player, Benchmark 3000 scoring system, student mobile phones, and CALL buttons were largely found to be not important.

Conclusion

This section addressed the first research question: How and for what purposes do faculty use technology in the ALC? Data analysis illustrated that there were two primary orientations, those included "instructor-centric" aspects of technology usage, such as the use of the podium as a command center, monitor utilization for presentation broadcast, the use of tablets as digital whiteboards, and instructor amplification using microphones, and a "Non-Instructor Technology Locus" which included the shared use of LCD's during class, the sharing of whiteboards, and device-facilitated participation via iPads, student laptops, and iClicker devices.

These findings are important for the literature on faculty development in technology as they provide insights into a variety of disciplinary use cases of ALC technology. Instructors frequently used tools that were familiar to them, and began class using technology that broadcast information to students. As class proceeded forward, the instructors encouraged or allowed students to use a variety of technology tools to engage with the course content and each other. This shift from a content delivery model towards a student-centered approach to teaching underscores the importance of the role of technology in supporting learning.

Educational classroom technology was utilized to help facilitate student learning in ALCs. Through surveys, observations, and consultations it was clear that many instructors sought to engage students with complex problems, particularly with whiteboards and digital whiteboards such as the Microsoft Surface tablet. These tools helped instructors engage closely with small groups of students, quickly compare different students' work with the entire class, and conceptually frame different aspects of their curriculum. The technology and the layout of the ALCs enabled instructors to move about the classroom more freely, though this occurred when students were working on activities in small groups. Bring-your-own-devices (BYOD) were the hallmark of ALCs as instructors encouraged students to bring these devices to class and in many cases use them. BYOD including student laptops, or instructor laptops or tablets, allowed the learning environment to be highly customized for both personal and digital collaboration. Digital and in-person collaboration occurred in classes when instructors asked students to problem-solve and provide peer feedback, which were easily incorporated into the space since technology integration was a focal point of classroom design. Instructors seemed empowered by the ability to connect with students and their classwork more quickly by accessing the technology resources which quickly displayed information.

These teaching principles were often facilitated by technology usage, but the student centered approach to teaching did not simply require technology, as some instructors utilized the space, chairs, and tables in unique collaborative ways and employed paper-based activities to engage students that used limited amounts of electronic technology. Instructors that used paper-based activities frequently employed some classroom technology usage for broadcast purposes, but facilitated flexible instructional activities with paper.

Overall, the data indicated how particular technology tools were utilized in the classroom by combining survey, observation, and consultation data. These technology tools and their use/non-use was important for understanding the adoption factors and barriers to classroom technology adoption discussed in the next section.

Section II – Barriers and Adoption

Introduction

This section is guided by the research question: ***What technology adoption factors and barriers were experienced by instructors in an Active Learning Classroom?*** Where the previous chapter largely addressed the technology tools adopted by instructors, this section will address why particular technology tools were, or were not, used in the classroom. Active Learning Classrooms were especially effective for studying this topic due to the plethora of tools available in each technology-rich classroom combined with the consistency of available tools across all of the classrooms studied.

Technology adoption factors and barriers to adoption were noted throughout the study, including time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. Each, it was found, could be either an adoption factor or barrier depending on context and whether there was an abundance or a lack of the resource. For example, when use of a technology tool saved time, the tool was more likely to be adopted; however, if a significant amount of time was required to learn and use the tool, this acted as a barrier to adoption.

Time

The pressures of time and time management were described by instructors and observed during their teaching. Based on initial survey data, only four instructors felt time was not a barrier to their adoption of technology. Six instructors felt lack of time was a barrier, and three were unsure. During the second survey, two more participants, eight in total, reported that lack of time was a barrier. Chandler captured this sentiment about lack of time when he said, “Ideally, I would love to be able to sit back and have the time to just reflect on how could I absolutely best teach this class, but there’re so many other demands on our time.” Even in class, instructors were very aware of time, as indicated by their careful use of timekeeping devices. During one observation, Marie used her Apple Watch as a timer for students working on a team activity. During a consultation, Lindsay illustrated how she used her instructor laptop to broadcast a ticking time-bomb onto the stadium monitor. She ensured that there was no sound, but the visual was used as a representation of time passing to keep the class on task. Alexis described the analog clock hanging on the Active Learning Classroom wall as “vital,” and said that “having a clock in a room helps me segment what I'm doing.” She said that she did not think it was a big deal when she first started teaching in the space, but that it has become an essential tool to help her break up her tasks and manage the class, especially as she tries new things that can take up time in unexpected ways.

This awareness of time also impacted other types of technology used in the classroom, with instructors gravitating towards tools that were efficient and time-saving. Tyson, for example, was keenly aware of time pressure due to the large number of students in his class (63) and the expectation of providing feedback to all of them as part of the student-centered approach in Active Learning Classrooms. This challenge motivated both Tyson and his department to adopt online peer feedback tools, such as iPeer, in order to provide feedback more efficiently. As a consequence of this adoption, students and instructors also began using laptops with increasing frequency because the iPeer platform was a web-based program that could be accessed using the laptops in the Active Learning Classroom.

Similar to the way in which Tyson used iPeer to manage time-related feedback challenges, Brian used a tablet as a more efficient method of content delivery. Using his tablet as an advanced digital whiteboard, he was able to quickly queue up stacks of handwritten math problems that he could then review with his students in class. Not only was this a quick way to archive his problem-solving steps for student learning, it also provided all the steps in one place that he could easily refer back to digitally, something not possible with traditional whiteboard technology. Convenience and in-class time-savings were also factors for instructors who emphasized student control of some of the classroom technology. Chris, for example, said that it was quicker and more reliable for students to use the wall-button technology to access LCDs and whiteboards than for the instructor to use the podium interface to accomplish the same task.

Technology adoption outside of the Active Learning Classroom also impacted teaching strategies and tool adoption within it. Alexis, an experienced Active Learning Classroom instructor, said that “I used to be a little more panicky about, like, the thing is not working and I need it to -- because I've got to get all the content covered.” In order to overcome this feeling and create more time for in-class activities, Alexis adopted a flipped approach to her classroom. After putting more of her content online for students to review so that class time could be used for more student-centered learning, Alexis noted that "we can be a lot more flexible and more relaxed." While building online resources to take the place of in-class content delivery, Alexis also spent considerable time redesigning her course to take advantage of student-centered teaching practices. This flipped approach allowed her to devote class time to activities like a play reading, student media presentations, and group project work instead of lecture.

While time-saving tools and techniques facilitated adoption, instructors also frequently described lack of time in class as a barrier to their use of technology -- though how this issue manifested could vary dramatically. Christi, for example, was very committed to the logistics of her class and aware of the limited class time available to her. She said, "I want to achieve a certain learning goal for my class, and I want to do it through a series of activities. There's not enough time to do all of those activities. I have to pick which activities I'm going to do for a particular day." Anderson found that using technology could also create time pressure in the flow of class. Even though he found iClicker useful for in-class student readiness assessment quizzes, he found that packing up all the equipment left him very rushed at the end of class since he had to vacate the room so the next instructor could set up.

For other instructors, the equipment cost them time *during* class due to malfunctions or other technical difficulties. Marie's students experienced issues with the physical connection between their table laptops and the team table monitors, and the podium control was not helpful in solving the issue. These technical difficulties resulted in frustration for both the instructor and students, and negatively impacted the amount of time available for teaching. As time was pinched, the collateral impact was that fewer pieces of actual technology were utilized. Only the table laptops and wall monitors that did work were used, and several groups of students did not have time to present.

Hans nodded towards similar concerns about effectively utilizing class time when asked about using the instructor microphone. Implying that a streamlined approach to teaching was essential, he said, "[Using the instructor microphone is] one more thing I could do, but it slows things down a little bit, and I never have enough time anyways." Brian echoed this logic when explaining why he chose to control the room from a student table rather than the instructor podium. After demonstrating that there are only a few buttons available at the student table as opposed to the more feature-heavy instructor podium, he explained that the "one click" approach available at the student table required lower cognitive load and maximized his time spent on teaching rather than managing the technology.

Finally, Anderson described time management issues in relation to meeting student needs. In Anderson's class, most students were declared music majors who often took credit overloads (18+ per semester). Additionally, these students had a daily evening music rehearsal. Anderson wrote in a survey that the schedule constraints of music majors combined with the pressure of implementing team-oriented pedagogy meant that he had to dedicate significant in-class time to project work. He said, "I feel that teamwork must be limited to the class time because my students' schedules are full and often do not align, making it difficult for teams to meet outside of class." Addressing the time constraints of his students impacted Anderson's ability to cover material in class, which also had a direct effect on the activities and technology used in class. His students had to maximize group work, which frequently took the form of team-based music analysis on paper as opposed to using all of the classroom technology equipment.

In all of the above cases, time was described as a significant factor related to teaching praxis, and the trade-off decisions that instructors made ultimately had a trickle-down impact on the technology employed in the Active Learning Classroom. Just as time savings motivated instructors to adopt some technologies, time pressures also acted as a barrier to adoption. When looking back at their first time teaching in an Active Learning Classroom, many new instructors especially wanted to have the time to properly redesign their course to take advantage of both student-centered approaches to teaching and time-saving technology tools.

Ease of Use

Related to the issue of time, instructors most frequently adopted technology that was easy to learn and easy to use. Tools like the LCDs monitors and whiteboards were frequently employed in part because of the relative simplicity of using them, especially when combined with the fact that they were familiar features from more traditional classrooms. Familiarity also played a part in the preference many instructors expressed for using their own laptop or tablet as opposed to the provided instructor computer. While instructors still used the podium touch interface to push source content to displays in the classroom, connecting to their personal devices allowed instructors to easily access their own content without the need for flash drives or file uploading.

In contrast, the tools that instructors most frequently chose to avoid were those perceived as requiring more effort than they returned benefits. In the case of the table HDMI connectors for student BYOD devices, instructors avoided incorporating them because students found them difficult to use. Call buttons and student microphones were also rarely utilized, generally not because of technology struggles, but rather because the purposes they served were perceived to be easier to accomplish without technology. As Alexis humorously remarked, "[students have] got this amazing, built in Call Button": raising their hands. Other instructors were simply unaware of the tool. As Chandler said, "I don't think I've even noticed [the call buttons] prior to this…. What's the use of it? How do I use it, or how does a student use if they want to?"

In the case of call buttons, lack of adoption was caused less by the effort of using the technology and more by the ease of doing without it. For example, instructors often expressed that they preferred to have students raise their hands instead of using a call button. Only two STEM instructors, Hans and Daniel, utilized call buttons for problem solving report outs in class. Lindsay, Mitch, and Alexis, on the other hand, exclaimed that the Active Learning Classroom call buttons reminded them of an air-hostess call button, with Mitch further saying they were "useless." Brian said students did not think to use it because hand raising was so much easier. He also questioned why there was only one call button at each table when he had two teams situated at each table.

Similarly, a number of instructors described the student microphones as unnecessary for their classes. While Christi said that she could imagine scenarios where "it might get quite loud" and the student microphones would be useful, in her own use case she said, "when they talk, everyone can hear." Tyson's conclusion was the same when describing a session where students presented brief presentations to the entire class: "Maybe at a certain point [student microphones] will be necessary, but I've got to say, for the elevator pitches they all stood up and delivered to the rooms. Even there they didn't use the microphone." For instructors like Lindsay and Marie, who required a number of in-class presentations, going without microphones was a chance for students to work on their ability to project their voices over a crowded room. Lindsay said, "I don't use the mics much partially because I want students to learn to project their voices. I haven't actually used them intentionally." Marie, who offered her students the choice of using the microphones or not, had a similar logic: "I say, 'If you don't want to use the microphone, then stand up and project your voice.' I tease them. I'm like, 'I've heard you outside. You have a voice. Don't be afraid to project.'"

When students were not presenting formally, some instructors found it easier to act as a human amplifier if necessary. Alexis, who had previously used the student table microphones in larger Active Learning Classrooms, said that she did not use them in her current small Active Learning Classroom because "there's no one that we can't hear. It's intimate enough and sometimes I will say, 'Could you say that again?' Or I will repeat what the person says to the room." Chandler also used this strategy in the same classroom as Alexis; he reported that "we ended up doing pretty much without the mics…I would say ‘speak up’, or repeat what they said.” Christi similarly found it easier and less time-consuming to simply monitor the classroom volume and respond without technology. She said:

> You can tell when they're just talking quietly, and you just say, "Hey, you in the corner, can you hear them," and they say, "No," and I said, "All right, speak up." They speak up a little bit and everyone can hear. That took me less time than teaching them how to use [the student table microphones], so I didn't bother to teach them how to use that.

One instructor, Hans, also had a technical complaint about his student table microphones: because of the way they were positioned on the table, students facing the wall might not be picked up when looking toward the center of the room -- as they would be when talking to the instructor. In general, however, instructors simply seemed to find the microphones easier to do without than to incorporate. As Christi put it, “They don't need them, so I'm not going to spend time teaching them how to use them.”

In a similar marriage of time-saving and ease of use, many instructors adopted paper-based activities despite the plethora of digital technology available in the Active Learning Classroom. Mitch, Christi, and Tim provided a paper packet of handouts to students, including problem sets that students worked through in class. Tim also distributed trivia quizzes on paper, while Chandler passed out paper handouts for students to work on individually. Paper was vital to the problem-solving aspect of the class because the paper-based system was flexible and allowed students to easily work together on the packets. In Lindsay's class, students wrote in a paper journal throughout the semester because the journal served as a physical archive that could easily be added to during each class. Teams of Anderson's students handwrote information on paper handouts that were submitted at the end of the class and brought back to the next one in a large portable file box. Anderson adopted paper-based tools because it was easier to use for student collaboration in two specific ways. First, the whiteboards lacked musical staff-lines and could not be used to archive work from class to class. Second, computer-based collaborative music notation software was not available, which rendered paper the easiest long-term solution.

Some instructors also found paper-based quizzing more convenient than the technologies provided in the Active Learning Classroom. Instead of the built-in audience response system, iClicker, Marie utilized IF-AT scratch cards as a quiz or summative assessment technique. These paper-based cardstock tools allowed students to answer a series of multiple choice questions by "scratching off" the correct answer. Brian initially used iClicker for a formative assessment technique to take the pulse of the class, but abandoned it in favor of paper voting cards that students held up in class during multiple choice questions. The paper card could be quickly folded to display a different multiple-choice response (A, B, C, D, or E) according to general questions that Brian raised. Since these questions were sometimes unstructured and always ungraded, the paper-based system was easier to use than entering the same questions into the iClicker audience response system. Describing his preference for the paper voting cards, Brian said, "With an iClicker, if you have a spontaneous question [you want to ask], there's multiple steps to go through. Whereas [with the paper voting cards] I can say, [hold up 'A' for [if you feel this] and 'B' [if you feel that], 'C' [something else]." In addition to the ease of asking spontaneous questions, Brian was willing to sacrifice the data collection functionality of the iClicker system for the accountability of the voting cards. "I actually like that it's not anonymous," he said. "I think this is part of the reason that I get the higher participation. Say you don't vote, I can sit there and stare at you." Despite the plethora of technology tools available in the Active Learning Classroom, Brian and others demonstrated that paper-based tools did sometimes offer flexibility and simplicity that technology could not easily provide. Instructors adopted these paper-based tools, even when a comparable technology option was available in the room, in cases where paper more effectively facilitated collaborative work, the distribution of problem-sets, or the quick and flexible execution of formative and summative assessment.

Troubleshooting Comfort Level

Instructor use of technology did not always go according to plan, and occasionally incidents of technology failure interrupted the flow of teaching and cost instructors valuable time. Instructors' reactions to technical issues correlate with their general level of comfort with troubleshooting and/or ability to persist with a positive attitude. These factors, in turn, correlate with instructors' willingness to adopt new technology. Overall, this cohort had a relatively high level of experience with both technology and Active Learning Classrooms, and exhibited a tendency to persevere in the event of technology failures. Though incidents observed during this study negatively impacted a range of technology devices, these incidents were frequently followed by the instructor finding a resolution or workaround and maintaining a positive attitude about using technology in the Active Learning Classroom.

The table below summarizes the number of incidents during observations one and two. Full descriptions of the incidents and the resolutions are available in Appendix M.

Table 11

Technology Failure Incidents

Instructor	# of Tech Incidents Observation 1	Observation 2	Total Incidents
Marie	3	1	4
Lindsay	2	0	2
Daniel	2	0	2
Hans	2	1	3
Mitch	1	0	1
Anderson	1	0	1
Tim	1	0	1
Alexis	0	0	0
Chris	1	0	1
Tyson	0	3	3
Chandler	1	0	1
Christi	0	3	3
Brian	1	1	2
TOTAL:	15	9	24

Note: Incidents were defined by the observer

Nearly all issues involved visual equipment glitches. LCD monitor incidents impacted eight instructors, and instructor laptop and podium control issues impacted four instructors each. A myriad of student laptop, table laptop, and connector issues were also observed. The lower number of incidents during the second observation suggests that issues with the classroom itself, such as a broken LCD screen, had been corrected through reporting and troubleshooting.

Despite glitches, many instructors demonstrated calm persistence in the face of technological hurdles. For example, when the autofocus on the document camera failed to work as he hoped, Brian simply paused class, waited for the autofocus to activate, and then proceeded. When a video embedded in Lindsay's PowerPoint failed to load, she immediately minimized her PowerPoint and launched a web browser to search for and play the same video there instead. At the start of Marie's first class, she attempted to project her Mac laptop to all LCD screens using the podium control and it did not work; however, by disconnecting and then reconnecting the devices in a step-by-step fashion, she was able to resolve the issue and proceed as planned. During a consultation, Alexis recalled a similar incident when she overcame two challenges with LCDs in her classroom and the podium control, both of which appeared not to work when her class started. She said the issue was simply that the devices were not powered on and that she always looked for a power button on malfunctioning devices. In another consultation, Christi described an incident when the podium display failed during class and she resolved the issue by moving to a student table and using the laptop affixed to the local LCD display to improvise an instructor podium. In each of these examples, instructors demonstrated the importance of both troubleshooting skills and perseverance in quickly resolving technology issues. When instructors possessed both qualities, they were more likely to feel confident about adopting Active Learning Classroom technology tools.

Instructors also persisted even when technology issues could not be immediately resolved. For example, while deploying practice iClicker quizzes to students, Anderson noticed that the real-time results were displayed in the wrong format. This error caused confusion for both Anderson and the students, but Anderson quickly brushed it off, emphasizing to the students that the quiz was a practice quiz and implying that the answers might not be wrong. Later in the period, as student teams worked on small projects, Anderson spent several minutes privately investigating the issue on his laptop. At the end of the class, he informed students that he understood the error: the iClicker base-station attached to his laptop was set incorrectly to display compiled results in "short-answer" as opposed to "multiple choice" format. In another incident involving iClickers, Hans brought a bundle of student iClicker devices and distributed one per table of students. A quiz was displayed to all LCDs via the podium and it yielded 11 responses -- one more than expected. Hans was confused, stopped the quiz, and asked his teaching assistants to toggle all the LCDs back to the wireless Microsoft Surface Tablet displays so he could address the topic another way without the unreliable data.

While tenacity and troubleshooting skill were likely to correspond to a willingness to adopt technology, a positive attitude towards overcoming barriers was also a factor. Christi demonstrated this attitude when she said, "If [technology is] getting in the way, we have to come up with solutions on the fly. I'm okay with that." Tyson, who often kept a positive attitude about technology he was unfamiliar with, said he felt comfortable asking students to help. He said "I haven't touched a PC since 2004...so I'll say, 'Hey is anyone able to use [Windows PowerPoint?]... Someone will just come up and do it. I'm totally cool with that.'" Alexis also exhibited a willingness to work around issues rather than avoid adopting technology. She said, "I've also become more confident and comfortable with not feeling like if the technology is not working, scrap it." She said that recently when something went awry, she would ask "everybody to take out a piece of paper" and that having a backup plan helped her to "not to get panicky when the technology [fails]." Hans expressed a similar sentiment while recounting a recent class in which the wireless projection system for his Microsoft Surface Tablet stopped working after 10 minutes. He said, "You just have to be ready to deal with the failure of technology...I have all my notes printed out and, worst-case scenario, I can put it on [the document camera] and project it." A positive attitude, combined with the security of a backup plan, allowed instructors to feel confident about adopting classroom technology even in the face of its challenges and occasional glitches.

Equipment Issues

Despite instructor willingness to persevere when encountering technology issues, sometimes the available Active Learning Classroom tools simply did not fully meet instructor and student needs or preferences. Two themes related to equipment availability emerged as notable barriers: lack of equipment necessary for a given discipline/department's learning needs and lack of compatibility with BYOD.

Lack of appropriate equipment.

Although instructors devised a variety of solutions and workarounds, ALC tools sometimes failed to meet both hardware and software needs. For example, Christi noted the lack of cellular service in her classroom and said that, without it, she was unable to contact classroom support in the event of an issue with the room. (As a workaround, she suggested installing a dedicated hardwired telephone in every Active Learning Classroom.) Since the STEM courses were required to have a lab component, STEM instructors adopted manipulables, sometimes electronic and sometimes not, to create lab activities inside the Active Learning Classroom. Christi and the lab assistant utilized a digital resistance-capacitor (RC) object to show how electricity works. She also utilized a video camera to capture the RC's oscillator display and broadcast it to the local LCD TVs where she could describe in real-time the sinusoidal curves generated by the electronic equipment. Brian also used manipulable objects to demonstrate physics concepts in class. He made use of the existing rolling chairs in the classroom to demonstrate a component of force, and he grabbed a yard stick and dropped it in front of the classroom to further illustrate as well. For more elaborate demonstrations, he used a camera that was stored in the closet. He said, "we have a big clunky video camera for larger demos... we just plug it into these [RCA to VGA] connectors [at the podium]." Brian used the video camera to capture in-progress lab demonstrations and broadcast them to all of the LCD TVs to make it easier for all of the students to see a close-up of the experiments.

Tyson and Chandler, on the other hand, suggested improvements for the existing equipment. Tyson, who advocated for Mac classrooms, was particularly critical of the Windows operating system installed on the student table laptops. The roaming profile setup utilized by Windows meant that students could experience login problems requiring the laptop to take several minutes to log into Windows. Chandler advocated for better student laptop equipment regardless of operating system, as he was most concerned with the quality of the physical hardware. He described the equipment as feeling “cheap” and emphasized specifically that the touch pads were not easy to use. His class required geographic information system work with maps that required precise digitization inputs, so he felt that the existing student laptops were inadequate and that a mouse would be better than a touchpad.

Some instructors also needed discipline-specific software that was not part of the standard technology configuration of the Active Learning Classrooms. Brian needed specialized physics software, though he felt that the student laptops took up valuable table space and said he would rather bring in departmental laptops stored in a laptop cart for when the software was needed. Chandler, on the other hand, requested that the university’s IT office install various open-source Geographic Information System (GIS) software on the student table laptops for computer mapping. After building the course and working with IT to get GIS software installed on the table laptops, Chandler found that many students brought their own laptops. “We weren’t at all expecting to have all our students bringing laptops” he said, “but the vast majority of them are.” When looking back, he recalled that he “didn’t know when we first started the class how many people would be relying on the laptops. It turns out only one student in here is using one of the laptops at the desk." In these cases, despite the time and resources invested in configuring the student table laptops, they could still go unused due to the students' tendency to bring and use their own devices.

Difficulties with BYOD.

In many cases, prevalence of BYOD in the classroom was driven by dissatisfaction with existing ALC equipment. In other cases, choices made at the individual college level impacted students' and instructors' decisions to use their personal devices. The College of Nursing, for example, required that students purchase iPads, and the College of Engineering had a laptop requirement for all students. Marie commented that there was pressure to make use of the iPads in her nursing class since students were required to buy them, and that this external pressure did not always directly align with the needs of her course. Daniel and Tim (Engineering) also commented on their department's laptop requirement; however, they did not seem to experience the same pressure to incorporate the laptops as Marie had. This difference in experience was likely because the laptop was less of a specialty device for students, and was therefore easier for instructors to incorporate into their classes.

When students brought their own devices, instructors often encountered compatibility issues between student devices and classroom display inputs. Daniel and Lindsay both noted that the BYOD laptops students brought to class often lacked HDMI outputs, and thus students who chose to work on personal devices struggled to connect their devices to the LCD monitor with the HDMI cable available at the team table. Lindsay noted that “a lot of students’ computers don’t have HDMI,” and Daniel agreed that “it’s pretty common for students not to have [HDMI] capacity right now with their laptops.” Daniel went on to describe how cumbersome, difficult, and sometimes prohibitive it was to queue up various student laptops from the instructor podium when they were unable to connect their laptop to the classroom interface. This labor-intensive process interrupted his teaching and frustrated him, which led him to not project computer-based problem sets around the classroom as frequently as he wished. For Lindsay, however, the frustration with BYOD device connection also served to promote the adoption of the table laptops: “That's where, I guess, the table laptop is really coming handy as we're asking students to project something and they have laptops that don't have the appropriate hookups.” Meanwhile, Hans said that even students who did successfully connect their laptops to the table connectors then struggled to adjust their laptop’s display settings to take advantage of the LCD screen.

Christi also described an issue with projecting student laptops. Her challenge originated at the podium control, where she experienced issues trying to figure out which student laptop to queue up from her central lectern location. She said, “it’s hard to tell” which computer to select when they are located at far away tables, so she has to “keep asking them” to identify the computer by number. In one class period, Christi explained, “we were doing presentations that were carefully timed,” and so the extra time added by the confusion caused her class to run slightly over its expected end. As a possible solution, it was suggested during a consultation that she use the Handheld Crestron

Display since it would allow her to toggle different displays around the classroom. However, she did not adopt it because she preferred the central location of the podium interface. She said, “It definitely has fewer options than the [podium control]...but I walk back [to the podium control] and control it here...I probably want to come back here to get everybody’s attention, because [podium control] is kind of the best place to talk to everybody.” Despite the challenges, she preferred the podium interface.

Mitch also experienced an issue with projecting content, but it was when sharing the screen of his own Microsoft Surface tablet over the classroom’s Wireless Projection System. A drawback of using this tool is that it reduces laptop or tablet resolution from a large 16:9 ratio to a smaller 4:3 ratio on the classroom stadium and wall-mounted LCD TVs. For Mitch, this was unacceptable because it reduced the amount of screen space he could write on using his tablet. While he stopped using the Wireless Projection System, he also said that, “if it was the same kind of resolution and aspect ratio as the [Surface tablet], then I’d use that wireless [projection] all the time.” Mitch wanted to adopt the technology, but was ultimately unable to because the available equipment did not perform in a way that matched his needs.

Finally, while other students were never barred from bringing their own laptops and mobile devices to class, the discussion about BYOD was somewhat limited -- perhaps because instructors were unsure how they could meaningfully incorporate them into the classroom. Brian, for example, opted not to encourage BYOD devices for his STEM classes and preferred a closed ecosystem of physics-specific devices to use for classroom experiments. When discussing the sensor hardware available in smartphones, he said that, while it was nearly ubiquitous, the challenges presented by each student using a different device would make BYOD too inconvenient. He said, "I don't want Bring Your Own Device because I don't want to be debugging." Marie, on the other hand, was in favor of incorporating BYOD devices such as iPads and laptops because, she said, "this is the world we're living in." She continued on to describe her class as an opportunity to navigate this world of BYOD devices, especially with the backdrop of the emergent telehealth field. However, she also felt it was difficult to incorporate the iPad meaningfully in her class, despite it being a requirement of the college.

Classroom Support

Since the Active Learning Classroom was a space outside their local college's domain, instructors were asked to describe whether lack of support acted as a barrier to their use of the room. Twelve of the participants surveyed said they disagreed with the statement that there was a "lack of technical support," with the remaining instructor neither agreeing nor disagreeing. Nine also disagreed with the statement that they had a "lack of confidence" in the Active Learning Classroom technologies, indicating that many instructors felt comfortable with the tools and the support in the classroom. Classroom support included features such as on-site troubleshooting, classroom laptop maintenance, and lecture capture support, and was provided by university staff who were on-site daily from 9 a.m. to 4 p.m. During consultations, participants reflected on how they could or did request equipment training prior to teaching in the Active Learning Classroom. They also discussed specific instances where they asked for on-site or “break-fix” troubleshooting services.

During consultations, some instructors reported reaching out to the university’s classroom support team for training prior to their first semester of teaching in an Active Learning Classroom. For example, Christi set up a meeting for a full tour of the equipment prior to teaching. Marie also said that she initiated an appointment with the classroom support team prior to her first ALC class two semesters earlier. She described practicing connecting her laptop to the podium control and pushing her laptop to various displays. She said that this test run with the equipment “made [her] feel better” because it provided her with experience with the tools and the knowledge of whom to call for assistance should a problem arise. However, she also noted that it still took her about a semester and a half to truly feel comfortable with the technology. Tyson also contacted classroom support prior to teaching in the Active Learning Classroom. He said that he had “major anxiety about this class” and that he was concerned he would not be able to find time to test out the room beforehand. When he met with the classroom support team, they spent 15-20 minutes going over the equipment and Tyson said that they were “really responsive and dedicated to the room.” This encounter gave Tyson a sense of confidence both in the equipment and in the team who would support his use of it.

Chandler, also teaching for the first time in the Active Learning Classroom, had hoped to set up a meeting with a colleague (who would also be teaching in the room for the first time) so that they could review the equipment on their own. When he and the colleague visited, they noticed a member of the support staff performing technology maintenance on the hardware, which gave them the opportunity to receive a brief and informal demonstration of the classroom features. Despite the quick overview, Chandler said that he is still not confident with the podium control since it is his first semester using the equipment to control the classroom. While he felt confidence in the technology support staff, he was also concerned with ensuring that all students had access to open-source software on the table laptops. However, he was ultimately able to work with the classroom support staff to install a variety of GIS software tools on the student table laptops in the weeks leading up to the start of the course and during the first week of its run. The classroom support staff were also able to facilitate a similar request from Christi, who needed voice analysis software to be installed on the student laptops.

In contrast to the instructors who toured the Active Learning Classroom equipment with the support team, Brian turned down the opportunity even though he was also new to the space. Instead, Brian's colleague (and co-participant in this study) offered him a five-minute "crash course" on how to operate the podium control. Then, Brian spent 45 more minutes working alone, pushing the various buttons and displays to figure it out himself. Brian opted to "play" with the equipment himself to learn it because he had experience teaching in a similar classroom at his previous institution. Therefore, he felt that preparing to teach in the room was more a matter of understanding the technological nuances of his new classroom than of becoming familiar with an Active Learning Classroom in general.

During class, on-site support for Active Learning Classrooms was available via a centralized help-line. None of the instructors utilized this service during the classes observed in this study; however, during consultations they discussed their experiences with the support team and most stated that those experiences were largely positive. Alexis favorably reviewed the team and said that, when she had a microphone issue, she called the "magic number" and someone arrived to fix the problem. Chris also said that, when he called classroom support, they arrived quickly to fix the issue he had reported. Marie agreed that the support team arrived quickly when she requested it, but noted that the request process itself proved challenging since she does not get cellular reception in her classroom. Christi similarly reported that she was unable to phone the support team due to lack of signal, and thus waited to report issues until after class when she could walk down and visit the support team in person. Lindsay did not report any problems in her classroom during the semester, but she said that the Echo360 lecture capture equipment was particularly problematic during her first semester teaching in an Active Learning Classroom the year prior. She reported this to a classroom support technician who provided updates over the course of several weeks as an underlying firmware issue was diagnosed and the faulty hardware was replaced.

Overall, instructors reported that reliable classroom support helped them to feel confident that they would receive answers to their questions about the technology in the classroom, and that technology issues would be resolved as they emerged. However, Marie also noted that support staff are not available during evening classes to provide on-call/on-site service. She reported that she had to take extra care to plan for technology failures during her evening class because of not having troubleshooting support on hand.

Building a relationship with the classroom support team was also a factor in instructor technology adoption. For example, Alexis recounted a day when a classroom support staff member was in the room while she was setting up and Alexis commented favorably to him about the podium control interfaces. The staff member offered to point out the annotation feature built into the system, and Alexis tried it based on his recommendation. She said she now likes to use it in her class, an adoption that would likely not have occurred if not for that conversation. Like Alexis, Mitch also said he built relationships with the classroom staff. Due to exchanges with them, Mitch said he has "learned all the tricks" for managing glitchy displays and it has reduced the frequency with which he has had to contact classroom support. For Hans, the rapport he formed with the support team enabled him to negotiate the storage of approximately 90 laptops in a classroom closet to be used for online exam periods. Hans also relied heavily on WPS, a product similar to Apple TV, which he asked the classroom support team to maintain in his classroom despite the University's adoption of the Apple TV standard in other Active Learning Classrooms. Each of these instructors was able to incorporate more technology into their teaching thanks to the support team.

Peer-to-peer Transmission

In addition to interactions with the classroom support staff, instructors also had interactions with each other which contributed to their adoption of technologies and teaching strategies in the Active Learning Classroom. In some cases, instructors had the opportunity to connect with each other between class periods as they transitioned into or out of the same spaces. Some instructors also hailed from the same discipline and therefore had occasion for more sustained collegial interactions that contributed to their adoption of technologies and teaching strategies in the Active Learning Classroom.

Since many instructors used the same teaching space, they were more likely to encounter each other in the transitional period between classes. This proximity allowed some of them to form an informal community of practice where they could pick up tricks or techniques from other teachers using the same space. Alexis, who taught theater, frequently talked with Chris, whose class on cancer research was taught just before hers. She said that she was inspired during passing conversations about the content of his class, and excited that the Active Learning Classrooms could be used for so many different types of disciplines. One concrete result of these conversations was Alexis's adoption of dice as a way to select teams in the classroom, a strategy she picked up from Chris while they were talking between class periods.

Instructors teaching in the same discipline were even more likely to share ideas and develop shared technology practices. For example, one classroom was exclusively used by Physics instructors, with Mitch and Brian teaching Physics I and Christi teaching Advanced Physics. This combination of space and subject overlap not only allowed them greater interaction with each other, but also allowed the instructors to customize the equipment for Physics classes, making technology setup easier for each class. All three instructors also adopted Microsoft Surface tablets. Mitch was the first instructor to begin using the Surface table for its digital inking properties, and then Brian and Christi adopted it as well based on his recommendation and the positive results in their own classes.

For all the benefit that instructors from the same department discovered when sharing an ALC, in some cases departmental standards could exercise a negative effect on technology adoption. This barrier was observable in the case of instructors who were teaching different sections of a single course that had a high degree of departmental oversight. These instructors discussed curricular aspects of the class with each other, and in-class teaching techniques passed from one instructor to another, which, as discussed above, can prove useful to technology adoption. However, because students in all sections were expected to have the same learning outcomes, these instructors had less autonomy in technology selection and adoption compared to instructors who taught a self-designed course. Tyson described this state of affairs as anxiety-producing, and said that “the anxiety had a lot more to do with the fact that I don't feel like I was driving the boat.” Mitch also described the shared curricular responsibility as “frustrating” at times, because he and the other instructor who taught the same class in the Active Learning Classroom held different views on course design, but were required to provide a unified experience for students. Departmental pressure and the decisions of other instructors teaching the same course also impacted the adoption of classroom technology and lab-based activities. For example, Tyson adopted the iPeer system because it was a solution used by all instructors teaching sections of the class. Similarly, the lab-based STEM classes taught by Mitch, Brian, and Christi required experiments, and as such they all adopted a video camera to broadcast these experiments. Ultimately, while Active Learning Classroom instructors might adopt technologies and strategies based on exchanging ideas with each other, the expectation of similar experiences between sections of a course could also mean that adoption was driven less by personal choice and more by majority opinion or departmental mandate.

Conclusion

The same factors that could influence technology adoption were often also potential barriers. For example, many instructors were very sensitive to the pressures of time, and so gravitated towards tools that were easy to learn, easy to use, and which were themselves time-saving. Tools that met these qualifications were adopted at much higher rates than those that did not. Technology adoption in general was also more likely when the instructor had a persistent and positive approach to troubleshooting. While the participants in this study were more likely to have these traits by virtue of their previous experiences teaching with technology generally or in an Active Learning Classroom specifically, their adoption was also frequently encouraged by a positive and trusting relationship with the classroom support team. Collaborative relationships with other instructors could also be a factor in driving technology adoption, as could departmental pressures such as mandates to incorporate particular BYOD devices beyond the Active Learning Classroom equipment.

Technology adoption and barriers to adoption are important for practitioners, researchers, technology vendors and a variety of other higher education administrators because education technology equipment is expensive to install, requires ongoing maintenance or staffing support, and upgrades in order to be reliable for instructors of the course of the product's lifecycle. Furthermore, pedagogical and technological trainings should be customized to the specific learning space. As noted, instructors that faced issues with the technology struggled to readjust their class time to account for the glitches which limited time in class for student learning. Additionally, some classroom technology equipment, did not meet the needs of instructors, so they opted to employ an alternative strategy, either not using a particular technology or asking students to bring their own devices. This is notable with the touch-display of the podium interface. Annotations and notes could be drawn on the lectern computer screen, however, instructors in STEM indicated that the Microsoft Surface tablet provided a richer more achievable and mobile annotation system compared to the podium interface. This suggests that adoption of BYOB and connectivity to displays and classroom equipment may be more important than a customized built-in set of equipment.

Adoption factors and barriers to adoption are intrinsically linked in the ALCs and mitigating these can maximize class time, reduce the fatigue caused by glitches, and lower costs for classroom buildouts by referencing both connectivity and flexibility over equipment availability. Additionally, understanding the unique technological affordances and use cases can help maximize student learning opportunities by providing instructors with easy to use tools that save time and engage students with pedagogical purposes, such as problem-solving, concept mapping, and peer-review that instructors discussed in their consultations.

Section III: Faculty Development Training & Technology Adoption

Introduction

This section addresses the research question: How does a semester-long faculty development intervention program impact instructors' adoption of Active Learning Classroom technologies? This experiential learning component of the study provided participants with exposure to new Active Learning Classroom technology tools and to a deeper understanding of how to use familiar tools more effectively in the classroom. Additionally, the experience helped instructors build resilience to issues and comfort with technology usage by exposing them to tips and tricks for adopting tools and overcoming technology barriers. Finally, the experience provided instructors with opportunities to think about their class with technology as a lens into their teaching.

The action research portion of the faculty development study was based upon the experiential learning model and provided one-on-one discussions, brainstorming activities, and hands-on technology training for instructors in the Active Learning Classroom. The four case studies below best represent the impact of the experiential learning model and illustrate the nuances of the individual conversations with faculty. Each case study is broken down into the various components of the experiential learning model where applicable: Concrete Experience, Reflection, Abstract Conceptualization, and Experimentation. Many of the study participants had prior Active Learning Classroom teaching experience, and thus there was a ceiling effect in terms of how much they learned during the study. For this reason, the case studies below highlight the experiences of the four newest Active Learning Classroom instructors. These instructors were the ones who benefited the most from the faculty development intervention program.

Case study 1: Chandler

Chandler, a new Active Learning Classroom instructor, interacted with seven classroom technologies during the action research portion of the consultation: the podium interface, the LCD displays, the wall buttons, the student microphones, the document camera, the Apple TV, and the student call button. During this portion of the study, Chandler gained insight into classroom technology tools and grew confident in his ability to use them during his class. He also considered how the tools available in the Active Learning Classroom could change his teaching by facilitating collaborative learning and inter-team communication. The vignette below is one example of how the experiential learning cycle improved Chandler's resilience and engaged him with these pedagogical ideas.

Concrete experience.

Chandler frequently used the podium to connect a laptop and to access the lectern PC; however, he lacked confidence in using the tool, especially after a class period where the system froze. He admitted that, "this is the kind of thing where I'm still learning." In order to practice using the technology, Chandler attempted to replicate the podium interface error during his consultation. He stood at the podium interface and began to select sources and outputs that would call up various whiteboards to be presented around the room to one of four output configurations: all A screens, all B screens, A+B screens, or stadium LCDs. Within moments, the system ceased to respond to his touch inputs. He said, “This is actually the kind of experience I’ve been having [with the podium interface]...I’ll do this kind of [finger input] thing and be like, ‘I think I’m doing the right thing?’” I told Chandler that this malfunction was a known intermittent issue with the system and directed him to the main power button so he could initiate a full power cycle. From my prior experience in the classroom, I knew that this reboot improved the system responsiveness. Chandler exclaimed, “There’s something I wasn’t shown before.” This exposure demonstrates a concrete experience with the hardware that resolved lagging system issues for Chandler that could help him save time resolving podium issues in class, and that also built his confidence with the Active Learning Classroom equipment.

Reflective observation.

While the system rebooted, Chandler noticed the small Crestron handheld control tool and began to play with it. He softly touched the various input and display menus, puzzled by why it did not reboot the podium interface. As he played with the device, Chandler began to talk aloud about his assumption that the Crestron handheld control was the master-switch for the podium interface. I explained that the podium interface and lectern PC were actually the master controls, while the Crestron handheld control acted as a portable input source manager that could be used for selecting and displaying LCDs or whiteboards. Through his reflective observations and our discussion, I identified his misconception and helped him to properly identify the master control in the podium interface and understand the functionality of the Crestron handheld control.

Figure 9 Learning the Podium and Crestron Interfaces

Note: Chandler, positioned on right in both photos, learns the difference between the podium interface and the Crestron handheld control.

Abstract conceptualization.

After discovering the differences between the podium interface and the Crestron handheld control, Chandler asked a question that was both technical and pedagogical: “One question with the A and B [displays]. Why was that designed? Why do you have an A/B? Are there applications for that that I’m not thinking of? Usually you just want to transmit to everybody?” This question allowed us to discuss the technological design of the Active Learning Classroom from a student learning perspective. I explained that it was designed to allow instructors to connect up to three digital input sources, and provided him with the example of displaying a printed agenda on the stadium monitors (by selecting the document camera on the podium interface) while two laptops could also be selected to present on the A and B wall-mounted LCDs. This example would allow Chandler to facilitate the Share-Its he had developed by allowing multiple student GIS projects to be displayed simultaneously for discussion, comparison, or developmental purposes. This strategy would be a more flexible and dynamic teaching style compared to simply transmitting one input to all displays. Chandler responded, “that’s a good insight.”

Active experimentation.

During the follow-up consultation, Chandler described how he had taken the idea of multiple inputs that he had gotten from the first consultation and applied it in his classes -- not only to displaying the student table laptops, but also to displaying multiple whiteboards. He described using multiple screens and the A/B LCD configuration, and explained how that made a difference in his teaching. He said that by using various screen inputs during Share-Its, “the whole class was able to see whatever achievement [the student teams] made” and, furthermore, there “was that cross-team dialogues about things.” The technical skills gained during our first consultation, combined with Chandler’s pedagogical question about the LCD TV configuration, transformed his teaching practice in the Active Learning Classroom.

Summary.

By replicating an issue with the podium interface during his initial consultation, Chandler learned how to reboot the system in order to resolve the problem. This knowledge gave him confidence that he could correct the issue by himself in the future, and so improved his resilience towards using technology in the Active Learning Classroom. Further, by challenging a misconception he had about the Crestron handheld control, the experience provided an opportunity to consider how the multiple input sources inherent in Active Learning Classrooms might be leveraged in his teaching. Chandler also used this experience as a talking point with other instructors. He said, “I've actually passed on that idea of Share-Its to a couple of my other colleagues, and that was a neat idea.”

Case study 2: Tyson

Tyson, also a new Active Learning Classroom instructor, interacted with three classroom technologies during the action research portion of the consultation: the podium interface, the LCD displays, and the document camera. He was excited to build his skills with the technology and manage the classroom more effectively. During this portion of the study, Tyson was exposed to several classroom tools that he later applied to facilitate peer-feedback in his business communication class. This case study illustrates how the experiential learning cycle helped Tyson employ these three pieces of ALC technology to facilitate student interaction.

Concrete experience.

Tyson expressed interest in learning about the document camera and the podium interface, as well as how they worked with the classroom LCD displays. During the first consultation, I showed him how the podium interface could manage multiple inputs and broadcast to different configurations of A/B/Stadium LCDs. To demonstrate, I connected a laptop to the podium interface so Tyson could practice broadcasting both the laptop and the built-in lectern PC to different configurations of LCD displays. I then connected the document camera, which allowed him to incorporate a third digital input into the configuration. To illustrate the document camera's versatility, I placed the screen of a laptop in its view and projected it, suggesting he could do the same thing if he quickly wanted to show something from a student laptop, tablet, or phone. Tyson's response was that he "was hyper impressed with the doc cam."

Reflective observation.

I brought Tyson to the podium to begin using some of the Active Learning Classroom technology, beginning with the podium interface. He soon discovered the digital inking feature and began reflecting on how it would be useful for providing feedback on student work as well as for focusing on elements on the screen during lecture. I also brought Tyson over to the document camera, connected to the podium interface to show him how to use it to broadcast student project work. He remarked on the document camera's effectivity: "Just the resolution of the thing...now I know!" I suggested that Tyson could also use it as a backup method for displaying student laptops or BYODs in addition to using the document camera to project hard copy student work. During the second consultation, Tyson reported that he had tried this, and said that the document camera "became a lot more useful" after I pointed out its potential. He said, "I would literally throw an iPad [on the document camera] if I needed to write something...Just knowing that I had this thing in particular meant that I didn't need to worry [about adapters]."

Abstract conceptualization + active experimentation.

Tyson wasted no time imagining how he might apply the podium controls to upcoming lessons. When Tyson initially discovered the digital inking features, he remarked, “That's cool though, because say I pull up my TA’s LinkedIn profile, we're talking about [LinkedIn] in class next time, and mark it red [using finger].” As Tyson reflected on the LinkedIn experiment, he began to play with the podium interface more to explore the possibilities of using multiple displays. He said, “The other thing I would likely do is if I've got [my laptop] up there ... Is there a way to [push] to those [A-Displays]? Do I hit the group A [button]? Yeah, there we go!” As he hit the button, he realized he moved the content to A-displays only and was able to answer his own question.

After Tyson learned to use multiple displays and inputs, he applied this knowledge to student peer-review activities by asking students to plug in their laptops to share their work. Students used their own devices or student table laptops to look at each other's LinkedIn profiles in their teams. Then they used iPeer to provide feedback and evaluate them with a Likert scale, as well as providing verbal feedback as they worked. Because we conducted the consultation in the Active Learning Classroom, Tyson could immediately link a conceptualization with an experimentation -- something that would not have been possible had the interview been conducted elsewhere.

Abstract conceptualization.

Tyson also continued to underscore how the classroom technology and the round tables in the learning space combined to foster strong peer review. He said, “When you're sitting in a huge lecture hall, they can't make eye contact with each other. They can't build a kind of rapport with each other. I think in this class, [the classroom layout] created this culture in which collaboration and learning could happen.” In addition to the physical configuration of the room, Tyson remarked that technology tools like the document camera, podium interface, and student devices (BYODs and student table laptops) were key to facilitating collaboration. These tools were especially valuable since his students were working with digital content like LinkedIn profiles, which would have been difficult to share in hard copy. Thanks to the technology, Tyson said, when “Johnny wants to share his resume, now everyone in his team can pull it up on the things in front of them... They're able to respond and they're able to give feedback to each other, so that was good.” By participating in this research study, Tyson was able to discuss and engage with the technological features of the Active Learning Classroom and use them more effectively to facilitate peer-feedback.

Figure 40 Multiple Displays

Left: Tyson (located on the right), selects multiple displays using the podium interface.

Right: Tyson discusses how he used multiple displays around the classroom to facilitate peer feedback.

Summary.

The experiential learning cycle enabled Tyson to build technology resilience in the Active Learning Classroom and inspired him to use the podium interface and document camera for peer-review. His positive experience with the tools and the activity made the Active Learning Classroom feel more valuable, and he wanted to know if I could provide research regarding the positive learning impacts derived from the design of Active Learning Classrooms. He said, “I'd love to share that over in my [department]... If you have any evidence and are able to share it, that would be wonderful.” I shared resources on learning-spaces literature covered in this literature review and the impacts these spaces can have on student learning.

Case study 3: Daniel

Introduction.

Daniel, like Chandler and Tyson, was a new Active Learning Classroom instructor. He interacted with three classroom technologies during the action research portion of the consultation: the wall buttons, the whiteboards, and the whiteboard cameras. During this portion of the study, Daniel was interested in showcasing how different teams solved engineering problem-sets, especially because his chemical engineering class was "all about solving problems." Students began with a word problem, changed it to "some sort of graphical and eventually mathematical formulation that [they] then have to solve," and then reported back on their answer. For many of his students, Daniel noted, it was "the first problem-solving class in chemical engineering" that they "really have to grapple with." This case study illustrates how the experiential learning cycle helped Daniel utilize Active Learning Classroom technology to accomplish his goal of facilitating problem-solving and displaying team problem-sets during class.

Concrete experience.

Daniel frequently modeled problem-solving in class using paper and pencil broadcast to the LCDs via the document camera. Occasionally, he would position himself at a student table and use that team's whiteboard to demonstrate problem-solving techniques. However, he explained that there were a few issues with this solution. First, the location limited the team's ability to use the whiteboard. Second, it was not always close to the podium where he kept his laptop. Third, it was difficult for all students to see a single whiteboard. In order to help Daniel take content from discrete locations around the classroom and discuss it further with the entire class, I demonstrated how the wall buttons activated the whiteboard camera to broadcast the content to the wall LCD screens. When I asked him if he had used the buttons, he said, “Those confuse me, so I don't know what they are.”

Figure 11 Wall Buttons
Note: Researcher (right) presses the wall buttons to demonstrate their function for Daniel.

Reflective observation.

After I showed him the wall buttons and demonstrated their functionality, Daniel reflected on how that option compared to his existing approach. He said, “I do everything when it comes to [pulling up] and presenting students’ whiteboards and laptop displays. I get with [the podium control], then I find whether it's [their] whiteboard, or sometimes I have to work to figure out which laptop is which, or which station [the student’s laptop is] at if I want to project something that they're doing on a personal laptop.” Daniel was not happy with this time-intensive process of selecting whiteboards or any other student-table content that he wanted to call-up for full-class discussion. Once he was introduced to the functionality of the wall buttons, he could immediately see that they provided a simple and time-saving solution to his problem.

Abstract conceptualization + active experimentation.

Much of Daniel's class involved students working in teams to solve problems, and this work frequently involved the use of the whiteboards. As such, Daniel immediately recognized the potential of the whiteboard buttons for his class and soon incorporated them into his teaching. During the second consultation, Daniel said that he now used the wall buttons more often in class. He said, "I'll find a group that's doing something that I like, and I'll go over and I'll do a quick lecture based off of what they're doing. I'll hit the AB button and I'll say, 'Look at the boards. Look at the screens and we'll talk about it.'" The wall buttons allowed Daniel to easily move to a student table, review the table's work, and display it around the classroom for larger discussion. The wall buttons also only pushed the student content to the surrounding student-table LCDs, which had the benefit of leaving Daniel's instructional content displayed for reference on the four stadium LCDs overhead. By adopting this technology, Daniel was able to be more flexible, save time, and be more responsive to student teams.

Summary.

After Daniel described the importance of problem-solving in the context of chemical engineering, I showed him how to maximize the whiteboards for problem-solving by using the wall buttons and whiteboard cameras. Though the active experimentation phase was not observed, his adoption of the wall buttons was confirmed in discussion. By adopting the wall buttons and whiteboard cameras along with the whiteboards, Daniel saved time compared to using the podium interface and was able to provide a richer learning experience for his students.

Case study 4: Alexis

Introduction.

Unlike the previous three instructors, Alexis had experience in the Active Learning Classroom; she was teaching her theater course for the third time in the space. During the action research portion of the consultation, Alexis engaged with three pieces of equipment: the podium interface, the LCD displays, and the document camera. Alexis had previously used the document camera to display hard copy text, but during this portion of the study she learned that it could also be used as a tool for displaying digital media such as students' Pinterest curation and various YouTube videos. This case study illustrates how the experiential learning cycle helped Alexis expand her use of the document camera and develop new strategies for capturing her students' attention and keeping them engaged in the work of the class.

Concrete experience.

Alexis's theater class incorporated a number of visual media and multimedia components. She frequently utilized Echo360 to record her class, and she also broadcast herself during class by standing in front of various whiteboard cameras while her TAs used the podium control to toggle the proper camera. Given her propensity for using classroom equipment to broadcast content, I suggested that she might also find the document camera to be a useful tool. I said, “[Instructors] like [the document camera], especially for old historic books or things [where] actually the print is most important.” It turned out that Alexis had used the document camera once previously:

> I used [the document camera] once for a reading actually. They hadn't done the reading and I was like, "Okay." They're like, "It's so intense we don't know how to do it." I said, "Let's do a closed reading together." I put it down here and I'm literally following with my finger “What does this mean, what does that mean?” They found that [process] to be very helpful.

Based on this positive experience, Alexis was interested in using the tool more frequently in her class. I showed Alexis how the document camera could be used to showcase visual media or physical artifacts with high fidelity and zoom capabilities.

Figure 52 Document Camera Usage

Left: Alexis (right) recalls document camera use for class readings in consultation one.

Right: Alexis (left) is shown additional document camera features by request in consultation two.

Abstract conceptualization.

After learning more about the features of the document camera, Alexis quickly identified an opportunity where she could apply the tool in her class. Conceptualizing her idea out loud, she said she would use the document camera during a future project:

> Actually, you've just given me an idea because [the class is] going to do culture jams. That's their next project and they have to make an adjusted ad or some kind of thing. For those of them that have something visual I think I'm actually going to use [the document camera]. This [displays the content] so crisp and clear and if they have done a spoof ad or something putting it [on the document camera] would be the way to [show it]. [Students] do a lot of things digitally, but that would be a place to show some sort of [physical] artifact.

Though Alexis appeared excited about the potential use of the document camera during her consultation, she did not use it during either class observation. However, by participating in the faculty development component of this research study, she developed the knowledge and skills necessary to utilize the document camera in a multitude of ways in the future.

Concrete experience + reflective observation.

Both consultations focused on the document camera because it enhanced the emphasis on visual and multimedia components covered in Alexis's class. After the first consultation, I observed a class in which Alexis had students perform a play in class. This observation inspired me to set up a concrete experience with the document camera to demonstrate how this Active Learning Classroom technology could also function as a performance tool. I pivoted the camera lens 90 degrees so it essentially mimicked a traditional video camera mounted on a tripod, then I sat in front of the camera and briefly pretended to be a newscaster presenting to the camera which was displayed to all TVs. The dialogue below again shows how Alexis progressed into a reflection:

> **Brad:** You just flip it, [the camera portion] has an accelerometer so it knows how to reorient itself
>
> **Alexis:** That's cool. I didn't know this could actually do that, so you just flip [the camera lens?]

Alexis: It's just picking up all [of you] - oh cool… Yeah, just one more thing to be able to do… you've helped me figure out things I didn't even know about.

Alexis added an extra function of a device that she already frequently used, and added yet another functional technique that she could build into her teaching portfolio.

Summary.

During the course of two consultations, Alexis engaged with concrete experiences with the equipment, reflectively observed what she saw, and, in the first consultation, abstractly conceptualized ways she could include the document camera into her teaching. When asked to discuss her thoughts about the overall Active Learning Classroom technology study, Alexis stated that this type of consultation helped her gain confidence to blitz through the "glitchiness" of technology failures and improve the quality of her teaching.

As the concluding activity for the action research/faculty development model, instructors were asked to discuss future technology desires for their Active Learning Classroom teaching. Nine of thirteen instructors provided solid, forward-looking abstract conceptualizations of technology in their Active Learning Classroom. The comments typically focused on using technology to flip their class or to improve the classroom hardware for their needs. Future faculty development programming could focus on these initiatives. Had this study and model continued forward, these goals would have been incorporated into the faculty development and action research process.

Conclusion

The newest ALC instructors received the most hands-on training on the classroom hardware during consultations, and this exposure to classroom technologies and troubleshooting tips allowed them to better understand the podium interface, document camera and wall-buttons while having an opportunity to reflect on their teaching. However, more experienced instructors were able to get something out of the experience as well, particularly an opportunity to review tools they'd previously used in their teaching and to think about opportunities to expand their blended or flipped classroom materials. Hans, an early adopter of the ALC stated that the part he most enjoyed about the consultations was the feedback provided. Anderson another experienced ALC instructor stated that "this study prompted me to consider ways that I might overcome barriers to adopting discipline-specific technology." Likewise, Marie stated that she enjoyed, "that it was interactive and included help and information about [ALC] technology." Ultimately, the impact of the faculty development intervention program on instructors' adoption of ALC technologies was helpful for those newest instructors to the ALCs.

Instructors with prior experience in ALCs often reflected on their teaching transition and how their instructional strategies either changed or were enhanced by the learning space. This suggests that technology proficiency and adoption occurred during prior semesters, but that the impact of both the space and the technology were important catalysts for discussing instructional strategies pertaining to teaching and learning.

Overall, the ELT framework and action research approach allowed faculty development consultations that specifically met instructor's needs. ELT and action research can serve as successful components of faculty development, and they are known to correlate with effective professional development and subsequently improve student achievement in class. While student learning is a latent outcome of faculty development, experiential learning is powerful and action-driven process that exposes instructors to a learning environment. This research process was social, active, and it connected instructors' prior knowledge and experience to their pedagogical goals. This research approach is an innovative new way of learning with a consultant that combines both expertise in education technology with pedagogical development.

CHAPTER 6

DISCUSSION

In this study, I examined the unique technological needs of instructors in ALCs by combining data from faculty observations, surveys, and consultations. The purpose of this study was to engage action research methods using Experiential Learning Theory (ELT) in order to investigate three research questions:

1. R1: How, and for what purposes, do faculty use technology in the ALC?
2. R2: What technology adoption factors and barriers were experienced by instructors in an ALC?
3. R3: How does a semester-long faculty development intervention program impact instructors' adoption of ALC technologies?

These questions are vitally important to the field of research and practice because they address gaps in the literature pertaining to teaching with technology in student-centered learning environments. Additionally, the methodological approach of this study differs from traditional approaches that focus primarily on gleaning data from participants. In this study, instructors also received technological and pedagogical support as it pertained to their particular teaching goals.

R1: How and for what purposes did faculty use technology in the ALC?

My primary research question addressed how, and for what purposes, faculty actually used technology in the ALC. Prior research in traditional classroom spaces showed that faculty often utilized technology for lower-order pedagogical learning activities that lent themselves to traditional teaching techniques, such as memorization (Reid, 2014). The purpose of an ALC, however, is to improve student learning by offering a space that encourages collaboration and active learning and minimizes lecturing. Therefore, it is important to examine if pedagogical shifts, facilitated by classroom technology, actually occurred as the designers and proponents of the ALC learning environments intended. Understanding how and why faculty use technology in the ALC is also important because instructors' technology use, and their prowess in using it, is directly linked to student acceptance of ALCs (Baepler, et al., 2016). Further, classroom design for these 21st century learners is an important and costly consideration for colleges and universities. ALCs are configured with expensive hardware and wiring, which are depreciating assets susceptible to wear-and-tear and failure. These technology-rich learning spaces require significant and ongoing staff support to maintain product updates, software patches, and firmware upgrades. They also present a challenge for instructional designers and faculty developers who might not have the proficiency, training, or bandwidth to support such a wide range of technology tools. Given all the potential costs of creating and maintaining an ALC, it is important for practitioners and administrators to assess the effectiveness of their configuration and explore alternatives for what innovative and efficient ALCs of the future might look like.

As part of the primary research question, this study explored whether faculty used more technology in an ALC than they did in a traditional classroom and whether they used technology in different ways. I found that the most frequently used technologies were those that were familiar from traditional (technology-equipped) lecture spaces that faculty had used previously. Faculty were most comfortable with content delivery tools, such as LCD TVs, the instructor podium, and whiteboards. Most faculty used these visual tools to deliver content to the class, and sometimes added audio components by using microphones and playing short videos or background music. These findings confirm Beichner et al.'s research (2000), which states that "the technology provides a focus for the students, bringing their attention to bear on the physical phenomenon being examined" (p. 5).

I found that the technology-rich environment of the ALC did not force faculty to abandon lecturing techniques, but rather encouraged them to adopt additional constructivist learning approaches in their teaching. In these scenarios, instructors frequently used potentially instructor-focused technology tools for non-instructor locus activities, something a traditional classroom does not usually allow for. As one example, faculty moved beyond traditional content delivery to more constructivist approaches by using LCD TVs to display student work or student problem-solving during class. The more class time and experience that instructors had in the ALC, the easier it became for them to engage with students in interactions facilitated by laptops, whiteboards, and LCD TVs. For instance, students used whiteboard spaces for problem-solving and concept-mapping, exercises which they then shared with the class in ways that reduced the amount of instructor-centric content delivery. Instructors were also able to utilize the same technology to more easily facilitate student learning, as the technology tools allowed them to quickly check in with teams, respond to student questions, and draw connections between problem sets or other content displayed around the classroom. Many instructors even shared control of the technology with the students, especially as the observation period progressed. These findings underscore the student-centered focus of the classrooms.

The ALC technology tools were found to be not only instructor-centered but also student-centered in their focus. This is an important finding, as technologies in traditional classrooms are nearly – though not exclusively -- instructor-centered. In contrast, the ALCs provided instructors with opportunities to apply active learning strategies that employed non-traditional or non-lecture-based activities to engage students with the course material in an independent and collaborative manner (Forsgren et al., 2014; Freeman et al., 2014b; Prince, 2004). The classroom technology tools and the unique layout of the ALC helped faculty to employ pedagogical techniques uncommon in a traditional classroom, including coaching, visiting students, check-ins with teams, and supporting projects run by small groups. The open flow of the classroom allowed instructors to easily visit student teams while the students worked with their BYOD laptops, the LCD TVs, and the whiteboards. The open layout also allowed students to physically congregate at their tables, while the whiteboards and LCD TVs allowed them to focus together on materials as well as easily display their work to the instructor and the larger class. The finding that the configuration of round tables and whiteboard spaces was vital to the student-centered approach to teaching and learning aligns with prior literature and research conducted in ALCs (Beichner et al., 2007; Beichner, Saul, & Allain, 2000).

Faculty also adopted technology tools that were required by departments or that met a particular pedagogical need. For example, Marie adopted iPads because they were required by the College of Nursing, while the STEM instructors all chose to adopt Microsoft Surface tablets because they found the digital inking feature particularly helpful for diagramming and mathematical problem-solving. Because the STEM faculty selected the Microsoft Surface tablets based on a teaching need they had identified, they found it easier to incorporate the technology meaningfully into their instruction. On the other hand, while Marie felt pressure to use a departmentally-required technology, she was left uncertain of the best way to incorporate it into her instruction. This example confirms prior research illustrating that strong pedagogical connections between teaching and technology are vital to incorporating technology well into the curriculum (Fleagle, 2012; Okojie et al., 2006; Reid, 2014). Given these findings, developers should be prepared to provide instructors teaching in ALCs with the technological training and support that faculty, by requirement or choice, are employing in their classrooms.

Despite the vast array of technology equipment available to instructors in the ALCs, not all of the tools were used by all instructors. For example, several instructors preferred for students to raise their hands rather than use a call button to get the instructor's attention, and both student and teacher microphones tended to be ignored in favor of the speaker simply raising their voice so the entire room could hear. Discipline-specific needs also factored into which technologies were adopted and which were not. An obvious example from this study revolves around audio. Hooper's use of the classroom's audio equipment helped him to train students on music theory concepts. Meanwhile, other instructors in this study -- such as Mitch, Chris, Chandler, and Tyson --

never made use of the ALC's audio equipment. However, this was unsurprising since their Physics, Biology, Natural Science, and Business courses respectively did not as naturally require or invite the inclusion of audio.

The underutilization of a number of the ALC technology tools begs the question of whether these classrooms truly need to be equipped with such an abundance of hardware. While most faculty in this study noted technology needs that the standard configuration of their institution's ALCs did not meet, there was no consensus in their opinions on which tools should be added and any suggested additions were often discipline-specific. It is therefore likely that tools added to the ALC to meet one discipline's specialized needs would be poorly adopted by the majority of instructors. Further, even classroom technologies more likely to see use across disciplines were frequently ignored in favor of an instructor or student's personal devices. Faculty reported a strong preference for utilizing their own laptop or Microsoft Surface tablet in the classroom, despite the fact that the ALC was already equipped with a computer at the instructor podium. Likewise, faculty across all disciplines found that students brought their laptops without prompting, even though the ALCs were already equipped with laptops for students. Even Chandler, who had course-specific open-source software installed on all of the student table laptops, found that "bring-your-own-device" (BYOD) laptops were preferred by students.

The preference for personal technology usage found in this study reflects the larger BYOD trend noted in the literature (Dahlstrom & Brooks, 2013; Dahlstrom, Walker, Dziuban, & Morgan, 2013; Good, 2013). Previous studies have found that a majority of students want to use their own devices in class, but that instructors often discourage the use of these devices in a traditional classroom because they are distracting, and so faculty seldom report creating assignments that take advantage of these technologies (Dahlstrom & Brooks, 2014). However, this study found that instructors either allowed and encouraged laptop and mobile device use in classes, or at least did not restrict their use. In the context of the ALC, personal devices represented less of a distraction due both to the plethora of technology built into the classroom and the pedagogical pivot instructors made from traditional lecture to shared engagement with the learning space that was underwritten by the classroom technology.

This movement toward BYOD represents a radical shift from a decade or two ago, when cost and access to computer equipment made it prohibitive for students to bring their own devices (Ertmer, 1999). While BYOD could be viewed as a competitor to existing technologies built into the classroom, research from ECAR has indicated that "students are very interested in instructors integrating the use of their (students') personal mobile devices into the coursework" (Dahlstrom & Brooks, 2013, p.38). As such, understanding this phenomenon in greater detail could provide insights into equipping future ALC learning environments more efficiently.

Taken together, the preference for BYOD, the discipline-specific use of certain tools, and the lack of consensus on potential additional tools all point to the futility of attempting to exhaustively outfit ALCs. Based on these findings, it can be reasonably assumed that no amount of equipment would be enough to meet the needs of all instructors, especially when variation across disciplines is taken into account. This study suggests that one viable alternative for future ALCs could be to scale back the classroom hardware to the most frequently used and adaptable tools -- such as round tables, whiteboards, wall-mounted LCDs, and wireless broadcasting -- while also taking advantage of the increasing number of internet-connected personal devices being brought into the classroom by students and teachers. These devices (e.g., laptops, tablets, phones) increasingly communicate across networks to share rich media and information with a growing backdrop of the Internet of Things (IoT). As technology costs decrease and personal device ownership increases for both students and faculty, higher education institutions will be continuously pressured to meaningfully integrate devices into the classroom (Dahlstrom & Brooks, 2014). ALCs that embrace this general orientation toward BYOD and connectivity could potentially minimize costs and expensive hardware updates over the long term. Future research might therefore explore what tools optimize student-centered pedagogies, how BYOD devices can be effectively incorporated into ALC environments, and whether a "scale-down" approach to ALCs could be effective.

R2: What technology adoption factors and barriers were experienced by instructors in an ALC?

In conjunction with how and why faculty use ALC technology, this study explored what technology adoption factors and barriers affected ALC instructors. Where the first research question provided insight into the technologies instructors chose to adopt and why, the goal of the second question was to identify shared contexts that influenced those choices. Looking at instructor technology use in ALCs through the lens of barriers and adoption factors demonstrates that technology usage is not just a matter of personal preference or individual pedagogical choices, but that it is also influenced by common motivations for or against using technology equipment. This perspective is especially important for practitioners engaged in ALC teaching and technology support who seek to better understand the needs of faculty in order to advance their use of technology in instructional contexts. In addition to providing insight into the challenges ALC instructors face, the results of this study also suggest support and incentives that might offset these challenges.

Adoption factors and barriers to faculty technology use have often been examined separately. Several scholars focus on a barriers approach (Ertmer, 1999; Schoepp, 2005), while others primarily investigate adoption factors (Anderson, Varnhagen, & Campbell, 1998; Medlin, 2001; Wilson, Sherry, Dobrovolny, Batty, & Ryder, 2002). Because some studies investigate both adoption factors and barriers as two separate categories (Keengwe et al., 2010; Kuker, 2009; Lin et al., 2014; Mrabet, 2009), the lack of consistency and unified terminology prevents a holistic understanding of these related issues. This study found that it was more effective to consider adoption factors and barriers in conjunction. Throughout the course of the study, instructors experienced adoption factors and barriers related to time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. Each, it was found, could be either an adoption factor or barrier depending on context and whether there was an abundance or a lack of the resource.

Time is one example of how the same resource can act as both an adoption factor and a barrier. Lack of time is frequently cited as a barrier to technology adoption in the literature (Al-Senaidi, Lin, & Poirot, 2009; Butler & Sellbom, 2002; Ertmer & Newby, 2013; Reilly, 2014; Schoepp, 2005), and this study also found that time was a common barrier in the context of faculty technology adoption in an ALC. Time as a barrier can apply to the limited time available in a class meeting or a semester, but it also applies to a larger context outside of the classroom. Most of the literature suggests that instructors lack sufficient time for developing technology-driven pedagogical activities (Lin et al., 2014), and Van Horne et al. (2014) found that faculty reported significant time was needed specifically to convert traditional classes to the new ALC environment. They also found that pressures at Research 1 institutions pushed instructors to devote more time to research compared to instruction, compounding the perceived barrier of the time needed for an instructor to become proficient in the use of ALC spaces and technology. In this study, several participants reported that a lack of time in class impacted their ability to conduct instructional activities that used classroom technology, while other instructors reported a more general lack of time based on commitments that they had in other areas of their teaching.

However, although time was often cited as barrier to using technology in the classroom, efforts to more effectively maximize class time also acted as a catalyst for technology adoption. For example, Tyson used student laptops to more quickly conduct peer feedback in his large class. Brian used his tablet as a digital whiteboard to create a more efficient method of content delivery. Marie and Lindsay brought BYOD devices to keep track of time in class. Chris encouraged students to toggle the wall LCD displays because it was quicker than performing the same action from the instructor podium. For these instructors, the time savings yielded by their use of technology were enough to outweigh any time costs associated with learning or using the tools. This finding is especially relevant to faculty developers and education technologists, who can leverage the link between adoption factors and barriers to improve programming and faculty support. For example, instructors who reported a lack of time as a barrier to technology adoption could be motivated by the long-term time savings and improved learning experience gained after one or two semesters of upfront technology adoption and training support.

This study also found that familiarity and ease of use could act as either adoption factors or barriers. LCD monitors and whiteboards were regularly adopted due to their relative simplicity as well as instructor familiarity with their classroom uses. Familiarity was also a factor in the frequency with which instructors opted to use their own laptop as opposed to using the classroom technology. On the other hand, unfamiliar tools more specific to the ALC environment -- such as the student table HDMI connectors, call buttons, and microphones -- were frequently not adopted. Faculty were especially disinclined to adopt tools when they were neither familiar nor easy to use, as was the case with the HDMI connectors which lacked adapters for BYOD laptops and were difficult to use to display laptop content on the appropriate monitor(s). In the case of the call buttons and student microphones, participants attributed the lack of use not to difficulties with the technology but to the fact that students had even easier alternatives in the form of raising their hand and raising the volume of their voice. Many participants also felt the same about the available instructor microphone. These tools were sometimes used in the ALCs but added a layer of complexity to teaching and learning that could easily be avoided by using either other technologies or none at all. This interest in simple, familiar solutions was also reflected in the number of instructors who used paper-based handouts, worksheets, and problem sets rather than digital alternatives.

Equipment availability was also potentially both a technology adoption factor and a barrier. While instructors were most likely to use familiar tools, teaching in an ALC made them more likely to experiment with (or at least inquire about) some of the unfamiliar tools they encountered in the space. The action research and experiential learning frameworks of this study also made it easy for faculty to ask about the equipment, particularly during consultations. These consultations made it possible for me to provide insights and rationales as to why the equipment might be useful in the classroom. In this way, the action research design of this study provided exposure to the abundance of technology available in the ALCs and acted as an adoption factor for many participants in this study. However, despite the fact that ALCs are designed to be technology-rich environments for all disciplines, the classrooms in this study often needed additional customizations to support particular disciplines and classes. For three of the Physics lab-based courses, for example, the ALC technology was supplemented with specialized lab equipment that required storage, protection, and staff support to maintain. Without the reserves of technology equipment stored in an adjacent closet, three participants would have been unable to conduct their class in the ALC. Identifying and managing these discipline-specific needs is an important consideration for classroom designers and faculty developers seeking to improve technology adoption in and effective use of ALCs.

In this study, institutional support also played a significant role in both promoting technology adoption in the ALC (when support was present and effective) and inhibiting adoption (when support was absent or insufficient). While institutional support is vaguely defined in the literature (Butler & Selburn, 2002), in the case of this study, like others

(Al-Senaidi et al., 2009; Butler & Sellbom, 2002; Reid, 2014; Rosario, 2012; Schoepp, 2005), institutional support pertains to support provided by a department or the university at large. In prior studies, lack of support, generally categorized, was frequently cited as a major barrier to technology adoption (Al-Senaidi et al., 2009; Butler & Sellbom, 2002; Reid, 2014; Rosario, 2012; Schoepp, 2005). In this study, however, many instructors did receive support to transition their course to an ALC environment through institutionally-provided troubleshooting assistance, classroom technology training, and faculty development. This study also found that technology support and training was frequently requested by instructors, either before the semester or during troubleshooting incidents, and that the availability and quality of this support impacted the instructor's pedagogical development as well as their successful adoption of classroom technologies.

In this study, 12 of 13 participants reported that they disagreed with the statement that there was a "lack of technical support" for their use of the ALCs. This study found that, when technical issues were reported, on-site classroom support was responsive and usually quick to correct the problem. The resulting positive and trusting relationship with the classroom support team encouraged faculty technology adoption. However, the reporting process for technical issues also acted as a barrier for some instructors. Because the classrooms did not have a landline and instructors did not get cellular reception within the rooms, any issues often had to be reported after class. Further, one of the classes was offered outside the hours when on-site support was available, which added an additional barrier to receiving timely technical assistance. In order to remove such barriers, the findings of this study suggest that care should be taken to provide continuous technical support to ALCs. For example, each classroom should be equipped with a reliable landline, with the telephone number to request support clearly displayed, and classroom support offices should be staffed in accordance with the classroom hours of operation.

Though classroom technology training was not proactively offered to instructors prior to teaching, several instructors requested and were given an orientation by the classroom support team. Given the relative technological savvy of these participants, the overall results might not be generalizable; therefore, faculty developers and educational technologists could be more proactive about providing training for ALC instructors, especially prior to and during their first semester teaching in the new learning environment. Faculty training for ALCs could include mandatory classroom technology training provided jointly by faculty developers and education technologists. Additionally, introducing faculty to in-person support staff members could help build a personal rapport between the instructor and the ALC environment. Finally, stationing educational technologists and faculty developers in the classroom, particularly for the first several class periods, could reduce the barriers to technology adoption by allowing instructors access to support staff as they're first interacting with the classroom technology and directly after a class is over. These recommendations for on-site staffing and assistance are supported by the research of other practitioners and scholars who have found that faculty development in technology is a unique field that bridges the gaps in various campus support functions (Collins, 2014; King, 2002; D. L. Rogers, 2000; Whitelaw, Sears, & Campbell, 2004). Such a collaborative approach anchored by a shared commitment to ALC learning environments could benefit instructors and practitioners alike.

This study found that technology adoption is also positively impacted when instructors participate in a community of practice which encourages them to share ideas with peers both within and outside of their discipline. Participants in this study learned strategies from other ALC instructors through departmental discussions about teaching and learning, a practice that was particularly prevalent amongst STEM faculty who shared a classroom and all adopted Microsoft Surface Tablets for digital whiteboarding. Several faculty also opted to meet with another instructor for an overview of the ALC technology rather than schedule a session with a member of the official support staff. These findings support previous research on faculty development which has shown that instructors enjoy having the opportunity to share ideas with fellow colleagues (Tyrell, 2015). Support staff could leverage this natural peer-to-peer transmission by facilitating faculty cohorts so that instructors know who else is teaching in an ALC learning environment, even if they do not teach at similar times in the same room.

Importantly, this study identified the transition between classes as an opportunity to expand faculty development training by connecting instructors and providing just-in-time support. I found that instructors informally shared insights across disciplines in the transition period between classes when one instructor was finishing with a room and the other was coming in to set up. The close physical proximity of the ALCs to one another, combined with many back-to-back course offerings, allowed instructors from within and across disciplines to meet one another and share advice regarding teaching strategies and technology use examples. This exchange of ideas emerged at two points: between Chris' and Alexis' classes, and between Christi's and Mitch's classes. Alexis conversed with Chris between class periods and, during the first consultation, said she learned from Chris how to randomly select teams to report out during class. Likewise, Christi and Mitch exchanged ideas about the Surface tablet in the minutes between their Physics classes. The data from the pre-class survey was vital for capturing this phenomenon, and the results of this study confirm the importance of peer support in technology adoption (Medlin, 2001). A more deliberate and sustained opportunity for faculty to meet, exchange ideas with each other, and mentor other ALC instructors would help create a network of resources and peer support that could be transformative for faculty development in technology. Support staff could also help build connections within and between disciplines in order to encourage sharing of information and success strategies, and to expose instructors to new ideas.

In future research, barriers to and adoption of ALC technology could also be studied from the perspective of online faculty learning communities (FLCs) or communities of practice, which are emerging in the literature (Beith, 2006). FLCs allow faculty to engage in professional development through both face-to-face and online venues using a variety of platforms (Brooks, 2010; Vaughan, 2004). Investigating technology adoption through FLCs, hybrid models, institute series, mentorship models, or peer-to-peer professional development network frameworks could further the research on instructors' knowledge-sharing across social networks (Rogers, 2000; Trust, 2015).

R3: How does a semester-long faculty development intervention program impact instructors' adoption of ALC technologies?

This research study was designed, in part, to address instructors' training needs in the ALC, such as learning about and overcoming difficulties with particular classroom hardware. In addition to providing hands-on technology support for faculty representing a cross-section of disciplines, the study also provided an opportunity for ALC instructors to reflect on and deepen the relationship between classroom hardware and their teaching practices. As I reviewed the surveys, observations, and consultation data with participants, instructors were provided agency, support, and an opportunity to reflect on their pedagogical technique and receive feedback to help them meet their self-identified goals for improvement. Both the hands-on and pedagogical support components helped instructors build their skills in a new learning environment and adopt technology in ways that aligned with their goals and teaching philosophies.

Research on the development of faculty is vitally important to the field of higher education, especially because instructors seldom receive prior pedagogical training (Austin & Sorcinelli, 2013; Gibson, 1992; Gillespie & Robertson, 2010; Mohr, 2016; Sorcinelli et al., 2006). In the case of ALCs, however, only a handful of prior studies address faculty transition from traditional to active learning classroom environments (Alwash, Grills, Hinrichs, & Wasserman, 2014; P. M. Baepler et al., 2016; Dahlstrom & Brooks, 2014; Van Horne et al., 2014). Instead, the primary focus of the literature on ALCs has been on student learning rather than faculty development (Beichner et al., 2007; Frazee & Gebre, 2012; Hughes & Frazee, 2014; Morrone, Ouimet, Siering, & Arthur, 2014; Van Horne et al., 2014). Given that many ALC instructors transition from more traditional lecture classrooms with fewer available technology options, their learning process is also an important factor in the success of the ALC environment. This is especially true because, as faculty transition to teaching in ALCs, they must make decisions about how they will situate their instruction in relation to the variety of technology tools available within the learning environment. Instructors in ALC spaces are also confronted with pedagogical challenges requiring them to apply student-centered learning strategies that are less commonly used in traditional spaces (Beichner et al., 2000; Beichner et al., 2007; Birdwell, 2016; Van Horne et al., 2014). The findings from this study add experiential learning consultations and in-situ exposure to the literature on faculty development and Active Learning Classrooms. This addition is important because it provides an evidence-based approach to faculty development research by engaging with instructors in the classroom about the best ways to assist them with using technology in their teaching.

The exploration of faculty development in this study was supported by experiential learning, the andragogical theory pioneered by Kolb (1984, 2014). Kolb's experiential learning theory (ELT) informed the creation of multiple research instruments -- including surveys, observations, and consultation guides -- which engaged participants in the four stages of experiential learning: concrete experience, reflective observation, abstract conceptualization, and active experimentation. These four phases allowed instructors to engage with the technology of the ALC and apply it to their teaching in a holistic, authentic, and comprehensive way. Combining technological and pedagogical training in each consultation addressed immediate instructor needs while also providing the opportunity for discussions that allowed faculty to reflect on their teaching and technology use and consider ways to improve their classroom practice. Prior research on faculty development suggests that instructors who learn more about teaching improve their instructional proficiency and ultimately improve student success (Rutz et al., 2012);

however, further research would be required to assess the long-term consequences of the faculty development provided in this study and its impact on student outcomes.

In the concrete experience phase of the consultations, faculty engaged with the ALC technology in sessions customized to each instructor based on classroom observations and their self-reported results from the surveys. The concrete experience provided just-in-time training for instructors as it related to their teaching, as opposed to a simple orientation to the classroom. To facilitate concrete experiences, all consultations occurred in the Active Learning Classroom. This provided two specific opportunities for the participants. First, the participants could engage with classroom technology tools in consultation with the researcher. Second, the instructor had the opportunity to use student-oriented tools such as the laptops and wall-buttons that might otherwise be unavailable or occupied during a normal class period. Therefore, as instructors engaged with the learning environment, they simultaneously investigated their pedagogical approaches.

Reflective observations allowed participants to think and talk about the technology and their own experiences using it. This reflection occurred when they were shown new technology tools or approaches and when they talked aloud about their experiences with the technology tools. The participants reflected on their experiences and compared tools' affordances and limitations to their thoughts on pedagogy and their current classroom practices. These reflective observations were important, particularly for new ALC faculty, because they connected a thoughtful approach to teaching practice with the technological possibilities of the ALC hardware. Instructors themselves also frequently cited the importance of the connection between technology and pedagogy during their consultations, despite an overt technology focus intrinsic to this study. Many instructors, particularly those with more experience in ALCs, articulated a strong commitment to using technology for active learning teaching practices such as problem-solving, case-based learning, and other student-centered approaches that engaged students with material and technology.

Abstract conceptualizations allowed participants to incorporate their concrete experiences and reflections into their specific teaching strategies and practices. During this phase of experiential learning, participants discussed how they might employ a technology tool or tools in their teaching. Similarly, they discussed or expounded upon reasons that they opted not to use tools. This phase allowed instructors to begin to create new forms of meaning about the classroom technology. In the four case studies, each participant linked their technology discussion to their pedagogy. For example, Chandler conceptualized how to use A/B television displays for Share-Its and Tyson extrapolated how he could utilize the digital inking on the podium interface to facilitate feedback on student work. In the active experimentation phase, participants then took these experiences, observations, and conceptualizations into their own classroom contexts to apply what they could. Due to the design of this study, the active experimentation phase was difficult to observe and was only able to be determined by the participants' self-reported statements. However, these statements did support the finding that increased participation in faculty development can foster additional awareness of teaching strategies that impact student learning (Y Steinert et al., 2012).

This study also supports prior research suggesting that it is especially important to address instructor transition to an ALC from both a pedagogical perspective and a technology perspective (Collins, 2014; Meyer & Murrell, 2014; Moore, Fowler, & Watson, 2007). In this study, the newest ALC instructors received the most hands-on training during consultations. The exposure to classroom technologies and troubleshooting tips allowed them to better understand the tools, while later phases of the consultation also provided an opportunity to reflect on their teaching. More experienced instructors had the opportunity to review tools they'd previously used in their teaching and to consider opportunities to use them more effectively or extensively in future classes. These findings suggest that there is a learning curve for ALC instructors, with new instructors more likely to be focused on grappling with the technological landscape while experienced instructors are able to explore more effective ways to use technology with active learning strategies in order to facilitate student learning. However, these areas of faculty development are not mutually exclusive, as both new and experienced ALC instructors in this study engaged in both technical and pedagogical faculty development during the course of the consultations.

Results from this study underscore how faculty development that incorporates training in both technology and pedagogy can help instructors make more effective use of ALC hardware while they are transitioning their teaching to the active learning environment. Since teaching philosophy and technology use are strongly linked, this study adds significantly to prior research on the complex topic of technology adoption in classroom spaces as found in Al-Senaidi et al., (2009), Lin et al., (2014), and Schoepp, (2005). The results of this study also support the finding that faculty development appears to be most effective when it is centered around faculty needs. (Austin & Sorcinelli, 2013; Gillespie & Robertson, 2010; Sorcinelli et al., 2006; Tyrrell, 2015). Action research methods had the greatest impact on the instructors who were teaching in the ALCs for the first time, as they had explicit and unique technological needs during the transition to the ALC space. However, more experienced instructors also discussed the importance of feedback built into the research study. Both Maria and Hans described that they enjoyed the one-on-one consultations, and that the feedback provided by the study was helpful. This confirms Tyrrell's (2015) finding that faculty report high satisfaction with feedback and prefer one-on-one trainings with educational consultants. These finding are particularly important for faculty developers and scholars to address in designing support for ALC instructors.

The findings of this study also indicate that there may be a significant gap in the support provided to instructors working in ALCs. While most participants in this study were veteran ALC instructors who had received pedagogical training on how to teach in an ALC prior to the study, I found that few instructors had received technological training that was linked to their teaching practices – a critical detail. Also, the classroom technology training they were provided was ad-hoc, with little proactive outreach from various departments. Many instructors received training only if they opted to request it. The positive implication, however, is that additional collaboration between instructors and support staff could foster a smoother transition for faculty into the learning environment. For practitioners, faculty development in technology is an approach to instructor support that can help to mitigate the challenges faculty experience in technology-rich learning environments (Collins, 2014; King, 2002; D. L. Rogers, 2000; Whitelaw, Sears, & Campbell, 2004). Additionally, increased collaboration across departments and between instructors could provide opportunities for more veteran instructors to showcase, model, or share their teaching strategies with other instructors.

Study Limitations and Directions for Future Research

This study has several methodological limitations that highlight both the possibilities and need for further research on faculty development and education technology in Active Learning Classrooms. The first limitation is that the small sample size, dictated by the qualitative and action research design, limits the external validity of results. Also, given the small sample size and short intervention period, many of the technological adoptions or uses of technology represent modifications to lecturing and substitution effects. Higher order components of SAMR, including modification or redefinition, were not frequently seen in this study. Replicating the study with additional participants, with a focus on instructors with less ALC classroom training, would add depth to these findings and allow for more general conclusions. Further, a longitudinal study covering the course design phase and first instruction in an ALC space would strengthen the theoretical framework underpinning this study by showcasing technology adoption over time. This design would also more accurately capture all phases of the ELT model.

This study would also have benefited from the incorporation of student achievement and student success data or end of semester data. Data from enterprise systems including the Learning Management System (LMS) or the Student Information System (SIS) would elaborate on student learning as it relates to faculty development. By combining data from multiple data sources, particularly those that investigate student success, the impacts of faculty development in technology could be linked to student outcomes. Future studies could also look at the student retention and success in ALCs compared with instructors' goals for ALC technology use and their beliefs about the impact of technology on student learning.

While it was beyond the scope of this study, this genre of research would benefit from a parallel exploration of student adoption and learning. As Stassen (2014) found, instructors new to ALCs frequently notice that student evaluations of their teaching suffer, particularly in the first semester. By exploring the technology adoption and learning experiences of faculty and students in the same classroom, a clearer picture of the technological capabilities and challenges of the learning environment could be achieved. Understanding how students and instructors interact through active learning pedagogies in ALCs is an important area of growth, and future iterations of this study could therefore incorporate observations and focus groups with students about the class. In a technology-rich environment like ALCs, new tools such as 360 VR cameras and voice recognition software (e.g. Alexa) could also be incorporated to observe the often nuanced conversations and interactions at each team table. This data has been traditionally quite difficult for observation protocols to gather (Birdwell & Hammersmith, 2015); however, new technologies could support more comprehensive observations in ALCs.

Another limitation of this study is that the largely qualitative results are contextually based on the parameters of the institution. Furthermore, the results are tightly connected to the very specific proprietary technology infrastructure incorporated into these classrooms. These factors limit the reliability and generalizability to ALCs at large. Further studies should be conducted at other institutions to address the unique situational contexts at other campuses. Subsequent studies could link datasets gathered by other departments.

While it is beyond the scope of this study, further research is needed to assess technology life-cycle, asset depreciation, and maintenance in ALCs. The essential classroom technology configuration for ALCs has not been investigated over sustained periods of time, and these findings would be important for classroom designers, administrators, and other stakeholders who seek to create to cost-effective learning environments that maximize student learning outcomes. As Good (2013) suggested, longitudinal studies could "address concerns that might appear after a year or two, including the durability of the equipment and how often the systems need updating to keep up with evolving technology" (p. 32). A longitudinal study of ALC equipment use could provide a more comprehensive understanding of classroom buildout needs that would allow for more functional and cost-effective choices in the future.

More research is also needed pertaining to the online and virtual technologies utilized in ALCs. In this study, many participants mentioned these tools and platforms, and flipped learning and other online pedagogical techniques are frequently encouraged in the ALC literature (McKnight, & McKnight, 2014; Michaelsen et al., 2004; Michaelsen, 2008; Yarbo, Arfstrom). The adoption of such tools is well-studied in traditional classroom environments, but their use in ALCs represents a new domain of exploration.

Finally, this study did not account for institutional context. Institutional culture and policy impact faculty development, education technology, and higher education research at large (Henderson, Beach, & Finkelstein, 2011), and institutional policies have also been found to impact technology adoption (Hamilton, 2009). These factors were beyond the scope of this study and would require additional investigation from genres such as organizational behavior. Corroborating this study with other data sources that support technology adoption, such as instructional design consultants and classroom support managers, would also provide deeper insights into why and how tools were adopted from an institutional perspective. If replicated at several institutions, these results would be more generalizable. Additional studies could also help identify general themes for the highly contextualized "institutional support" variable that has so far not been well-defined in ALCs.

CHAPTER 7

CONCLUSION

While universities have made significant financial and institutional investments in constructing technology-rich classrooms, much remains to be explored in terms of implementing sound, theoretically-informed, and practice-based pedagogy for the effective use of such technology by faculty. Promising literature exists on alternative learning classrooms (ALCs), characterized by their ability to provide students with opportunities to engage in non-traditional, non-lecture-based activities that, independently and collaboratively, engage them with the course material. ALC research illustrates that the classroom design can support the socialization and problem-solving aptitude of students, which are key factors for fostering the kind of student-centered learning essential to active learning performance and success. Yet the pedagogical pivot instructors have experienced transitioning from a traditional lecture classroom to a technology-rich, student-centered ALC has been described as overwhelming. Redesigning learning objectives, assessments, and instructional strategies to foster student-centered learning can be challenging for many instructors who are more familiar with traditional approaches to teaching in traditional lecture spaces.

Thus far, research on the impact of technology-enriched learning environments like Active Learning Classrooms has typically centered around student learning. Less attention has been paid to the faculty development needed for instructors to properly take advantage of these environments and their technology. In the wake of the evolving field of faculty development, which has resulted in part with the creation of Centers for

Teaching in higher education offering a place for professional development, recognition, and reward to faculty, more support exists than ever before on various aspects of teaching. This support has taken the form of pedagogical support programs, fellowships, and workshops. Yet a great deal more is needed in terms of providing help specifically aimed at assisting instructors in their transition into ALCs.

This study followed a group of 13 faculty members in multiple disciplines teaching in ALCs. In this study, I examined the unique technological needs of instructors in ALCs by combining data from faculty observations, surveys, and consultations. The purpose of this study was to engage action research methods using Experiential Learning Theory (ELT) in order to investigate three research questions: First, how and, for what purposes, do faculty use technology in the ALC? Second, what technology adoption factors and barriers were experienced by instructors in an Active Learning Classroom? Third, using Kolb's experiential learning theory (1984, 2014), how does a semester-long faculty development intervention program impact instructors' adoption of Active Learning Classroom technologies?

I adopted a methodological framework specifically designed to provide a diverse set of qualitative and quantitative data in order to better understand the unique aspects and challenges of technology integration experienced by instructors in Active Learning Classrooms (ALCs). I developed surveys, consultation interview protocols/guides, and observation protocols using prior research, existing instruments, and Kolb's Experiential Learning Theory. I obtained Institutional Review Board (IRB) approval [Protocol ID: 2015-2864] in accordance with university policy for human subjects research (see

Appendix A). I selected a large research university with new Active Learning Classrooms for this research study. These classrooms were chosen because of their technology-rich designs and because of the diversity of instructor disciplines and teaching experience in these classrooms. The consultation instruments involved active participation from both the researcher and the instructor. Data collection activities occurred over a 14-week semester during Spring 2016.

Results indicated that the most frequently used technologies were those that were familiar from traditional (technology-equipped) lecture spaces that faculty had used. Faculty were most comfortable with content delivery tools such as instructor laptops connected to the LCD TVs, the instructor podium, and whiteboards. Instructor technology usage in ALCs could largely be classified into one of two categories, the “instructor-centric” perspective or “non-instructor technology locus” perspective. Instructor-centric technology usages included the podium as a command center, monitor utilization for presentation broadcast, the use of tablets as digital whiteboards and instructor microphones for voice amplification. Non-instructor locus examples included the shared use of LCD’s between instructors and students, the sharing of whiteboards primarily for problem-solving, and device-facilitated participation via iPads, student laptops, and iClicker devices. These technologies and their use/non-use were important for understanding adoption factors and barriers to classroom technology adoption.

At the beginning of instruction, given that the instructors were veteran ALC users, most blended classroom setup with other pre-class activities. Many deliberately used multimedia variously as a pleasant way to help students transition into the classroom environment, as a means to connect daily content with course themes, and as a subtle way to express their personality. Following up on a pilot study suggesting a potential barrier to learning afforded by a mismatch between available classroom software/hardware platforms and teacher preferences, I found that tension was indeed generated early on when the common preference of instructors for the Mac platform was frustrated by constraints to use the Windows platform.

The technologies most frequently employed in participating ALCs included wall-mounted LCDs, the podium connectors for laptop or other input source connection (e.g. HDMI, VGA), the Crestron podium interface that routes various inputs and sources, the whiteboard, the stadium LCD monitors, and the instructor's personal laptop. Instructors welcomed the ease with which the latter was connected, and the way their own styles could be accommodated by being able to use their laptop. Most instructors configured their classes with the podium at the center, although a few altered this configuration because they preferred not to have any students situated behind them.

The Crestrom podium interface frequently served as the location of an important "hub" or command center through which an instructor could direct class activities. It connects various sources –including the lectern computer, document camera, DVD player, and personal devices like laptops and tablets– to the stadium and wall-mounted TVs. Instructors often projected their PowerPoint presentations to the stadium monitors. However, for pedagogical reasons (to give students more time to engage with one another) or practical reasons (difficulties reading), some limited this screen time. The adoption of some technologies differed by discipline. For example, the Surface tablets were primarily adopted by STEM instructors, who looked at them as a more convenient form of whiteboard. As an example of a gendered perspective on technology, one instructor refrained from using the class microphone because its reliance on pocket placement was deemed to favor typically male clothing. While many instructors used TVs to broadcast information, several also allowed input from students in terms of what was displayed on the wall-mounted monitors. For example, the monitors allowed team tables to show their progress to the instructor and to the entire class. Where the LCD TVs were the primary device for broadcast, whiteboards were the primary problem-solving, ideation, and collaboration tool in the classroom. The board both enabled students to solve problems themselves, and allowed teachers to gauge student progress. Satisfaction with the new whiteboards was not universal as some instructors felt they were too small compared to the traditional wall-mounted boards on which they could place a great deal more information. The whiteboard did stimulate interactivity in that the content could be switched to that of different student groups or teams to discuss varying approaches to a problem. Technologies like iClickers and cell phones were also effectively used to support student interaction. This study highlighted the complexities of TPACK (Chai, Koh, & Chin-Chung, 2013, Mishra & Koehler, 2006, Rienties et al., 2013, Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013), where many skillsets must be combined for effective technology integration. In TPACK, instructors must navigate between technological, pedagogical and content knowledge as they instruct.

For this research study, instructors substituted some tools for others; this was particularly evident with student whiteboards for problem-solving activities and instructors use of Microsoft Surface tablets for digital white boarding. The technology substituted and augmented the instructional practices, but stopped short of modifying or redefine the instructors' pedagogy.

This study found specific technology adoption factors and barriers to adoption in ALC classrooms, including time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. Importantly, this study linked adoption factors and barriers to adoption. In other words, the same factors that could influence technology adoption were often also potential barriers. Technology adoption of classroom hardware was generally found to be more common amongst instructors who exhibited a persistent and positive approach to hardware troubleshooting. The participants in this study were frequently encouraged by a positive and trusting relationship with the classroom support team. Adoption was also found to be facilitated by two external factors, fellow peer faculty and department mandates. Peer relationships with other instructors drove the adoption of particular technologies, particularly the Microsoft Surface tablet. Department mandates also pressured faculty to incorporate particular BYOD devices beyond the standard ALC equipment. The most frequent barriers to technology adoption were time, ease of use, equipment availability, institutional classroom support, peer support, and instructor comfort levels with technology and troubleshooting. The newest Active Learning Classroom instructors received the most hands-on training on the classroom hardware during consultations, and the exposure to classroom technologies and troubleshooting tips via an experiential learning framework allowed them to better understand the podium interface, document camera and wall-buttons while having an opportunity to reflect on their teaching.

"Faculty training in the integration of technology into pedagogy is critical; faculty must be trained in the use of the tools, not just given access to the tools"
-Keengwe et al., (2010)

APPENDIX A:

INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

University of Massachusetts Amherst
108 Research Administration Bldg.
70 Butterfield Terrace
Amherst, MA 01003-9242

Research Compliance
Human Research Protection Office (HRPO)
Telephone: (413) 545-3428
FAX: (413) 577-1728

Certification of Human Subjects Approval

Date:	January 8, 2016
To:	Bradford Wheeler, Teacher Educ & Curriculum Stud
Other Investigator:	Torrey Trust, Teacher Educ & Curriculum Stud
From:	Lynnette Leidy Sievert, Chair, UMASS IRB

Protocol Title: Adopting Team-Based Learning (TBL) Classroom Technology and Overcoming Barriers: A Faculty Development Intervention Model for Technology-Enhanced Learning Spaces
Protocol ID: 2015-2864
Review Type: EXEMPT - NEW
Paragraph ID: 1,2
Approval Date: 01/08/2016
Expiration Date: 01/07/2019
OGCA #:

This study has been reviewed and approved by the University of Massachusetts Amherst IRB, Federal Wide Assurance # 00003909. Approval is granted with the understanding that investigator(s) are responsible for:

Modifications - All changes to the study (e.g. protocol, recruitment materials, consent form, additional key personnel), must be submitted for approval in e-protocol before instituting the changes. New personnel must have completed CITI training.

Consent forms - A copy of the approved, validated, consent form (with the IRB stamp) must be used to consent each subject. Investigators must retain copies of signed consent documents for six (6) years after close of the grant, or three (3) years if the study is unfunded.

Adverse Event Reporting - Adverse events occurring in the course of the protocol must be reported in e-protocol as soon as possible, but no later than five (5) working days.

Completion Reports - Notify the IRB when your study is complete by submitting a Final Report Form in e-protocol.

Consent form (when applicable) will be stamped and sent in a separate e-mail. Use only IRB approved copies of the consent forms, questionnaires, letters, advertisements etc. in your research.

Please contact the Human Research Protection Office if you have any further questions. Best wishes for a successful project.

APPENDIX B:

ACTIVE LEARNING CLASSROOM TECHNOLOGY LIST

University purchased technology equipment for one Active Learning Classroom

HB COMMUNICATIONS INC.

Item #	Qty	Manufacturer	Model	Description
37	12	Crestron	DM-RMC-SCALER-C	HDBT Receiver/Scaler, Copper
38	7	Chief Mfg	PNRIWUB	Swing-Arm Wall Mount
39	7	Samsung	ED65C	65" Flat Panel Display, Commercial
40	4	Chief Mfg	Structural Adapter	Structural Adapter as required
41	*1*	*Chief*	*LCM4U*	*LCM Large Ceiling Multi-Directional Solutions*
42	4	Samsung	ME46B	46" Flat Panel Display, Commercial
Control System				
43	1	Crestron	AV3	Control Processor, Medium
44	1	Crestron	C3RY-16	Control Card, 16 Relay
45	1	Juniper	EX2200-24P	24-Port Managed PoE Switch
46	1	HP	L2206TM (B7F36A8)	Touch Sensitive Monitor (No Stand)
47	1	Ergotron	LX 45-241-026	Monitor Mounting Arm
48	*0*	*Crestron*	*C2N-FT-TPS4*	*Flip-Top with Touch Panel*
	21	*Crestron*	*C2N-FTB-D-B*	*FlipTop™ Control Center, Buttons, Black*
49	4	Crestron	CNTBLOCK	Main Distribution Block
50	4	Crestron	CNPWS-75	power supply
51	2	Crestron	CXNRMAK	rack mount (holds 3 units)
52	7	Crestron	CNTBLOCK	Table Distribution Block
53	1	Crestron	CNPI-48L	Button Panel Interface, LED, 48
54	7	Sandies	340 Series, LED, "CALL"	Call Sign, Lighted
55	1	Crestron	TST-600-B-S	5.7" Wireless Touch Screen
56	1	Crestron	CEN-ERFGW-POE	Wireless Gateway
57	1	Extron	60-1081-12	USB HUB4 AAP
58	1	Extron	60-593-02	AAP 100 mounting frame
Racks and Power				
59	1	Middle Atlantic	UPS-1000R	UPS, 1000KVA rack mount
60	1	Middle Atlantic	MPR-9 w/RLM modules	Vertical Power Strip, Multi-Circuit
61	1	Middle Atlantic	USC-6R	Power Sequnce Controller
	1	*Extron*	*60-1397-02*	*Cable Cubby 1200, Black with power*
Assistive Listening System				
62	1	Williams Sound	PPAT45	Transmitter w/ Rack Mount
63	1	Williams Sound	ANT 029	Antenna, Articulating
64	1	Williams Sound	IDP 008	Signage Kit
65	4	Williams Sound	PPA R35-8N	Receiver
66	1	Williams Sound	NKL 001	Neckloop Induction Coil
67	4	Williams Sound	EAR014	Dual Ear Bud
68	4	Williams Sound	HED 027	Stereo Headset
69	1	Williams Sound	CHG 3512 PRO	Charging/Carrying Case, 12 Unit
70	4	Williams Sound	BAT 026-2	Re-chargeable Batteries, pair

HB COMMUNICATIONS INC.

Item #	Qty	Manufacturer	Model	Description
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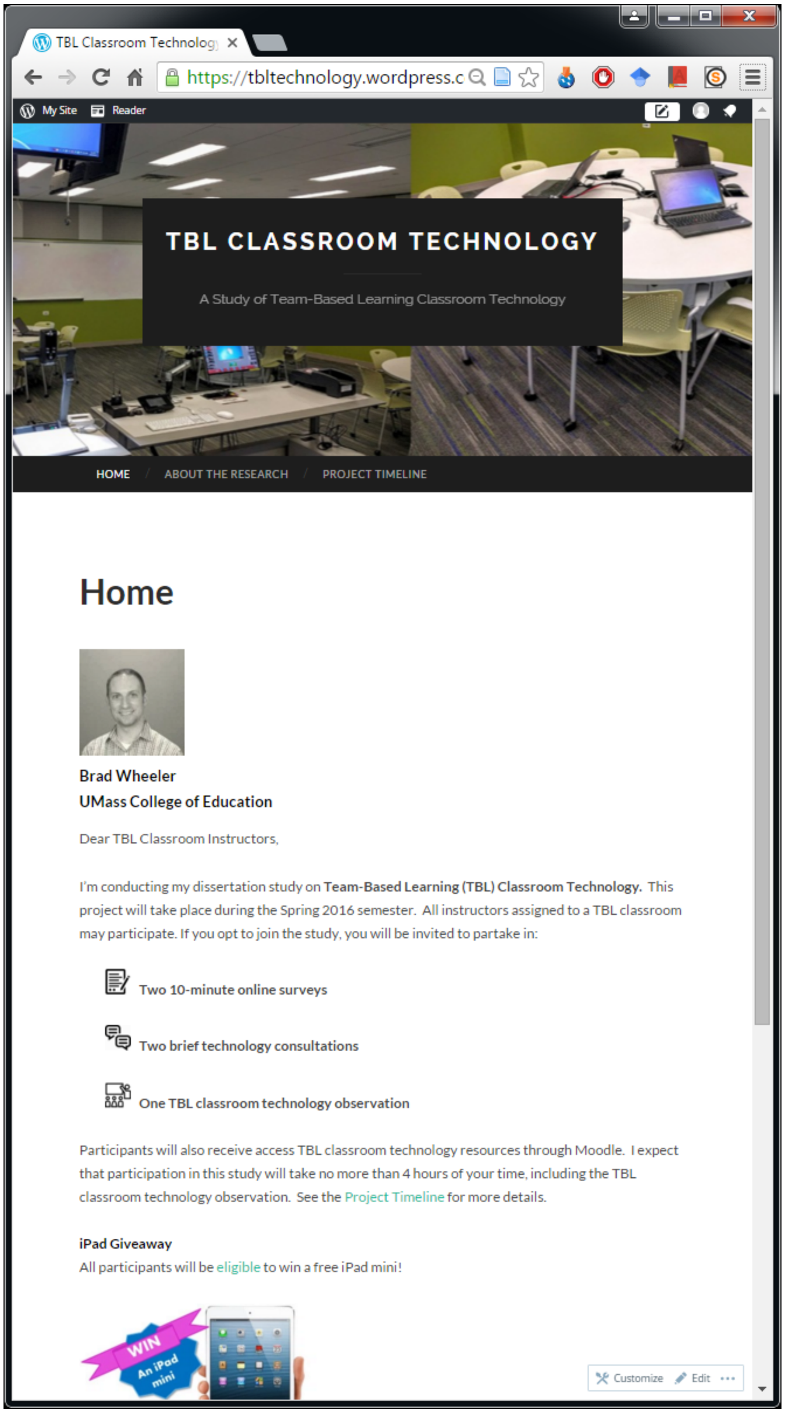
70	4	Williams Sound	BAT 026-2	Re-chargeable Batteries, pair

APPENDIX C:

RECRUITMENT WEBSITE



Source: https://tbltechnology.wordpress.com

APPENDIX D:

CONSENT FORM FOR PARTICIPATION IN A RESEARCH STUDY

Qualitative Instrument

University of Massachusetts, Amherst

Researcher(s): Bradford Wheeler, (Faculty Sponsor: Dr. Torrey Trust)

Study Title: Adopting Active Learning Classroom Technology and Overcoming Barriers: A Faculty Development Intervention Model for Technology-Enhanced Learning Spaces.

1. WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to understand the perceived barriers and adoption factors experienced by faculty when implementing educational technology into team-based learning classrooms at [redacted]. The results from this survey may be included in the researcher's comprehensive exams, dissertation, and may be included in manuscripts submitted to professional journals for publication.

2. WHERE WILL THE STUDY TAKE PLACE AND HOW LONG WILL IT LAST?

The study will take place at [redacted] the Spring of 2016. A survey will be administered electronically through Qualtrics, followed by an interview, classroom observation, and final interview plus survey. This study will take approximately 3:50 minutes total, plus additional time participants decide to dedicate to resources. Interviews will be conducted in an Active Learning Classroom at [redacted] campus. Each interview is expected to last up to 1-1.5 hours. Observations will occur in the Active Learning Classroom space you are assigned to. You may be contacted in the future for follow-up but only with your permission.

3. WHAT WILL I BE ASKED TO DO?

If you agree to take part in this study you will be asked to complete an online survey followed by two interviews and a classroom observation. The full sequence is listed below: Online survey, Interview, Classroom observation, Interview, Online survey. You will also be given access to Active Learning Classroom technology resources online resources through [redacted]. During the interview, you will be asked to answer questions regarding your experiences with technology use, adoption, and implementation. In addition, you will be asked about your experiences with technology use, and teaching in other non-[redacted]. The classroom observation protocol will focus on your instructional use of Active Learning Classroom technology. Your participation in any of the data collection activities is completely voluntary and you may skip any questions you feel uncomfortable answering. Similarly, you may stop your participation in this research project at any time. With your permission, the interviews will be audiotaped.

4. WHAT ARE MY BENEFITS OF BEING IN THIS STUDY?

You may not directly benefit from participating in this research, however you may have the opportunity to reflect on your prior experiences as a faculty member which may enhance self-understanding and change behaviors about technology use. The information you share will be used to design and support faculty development initiatives regarding classroom technology integration. Results of your participation may be beneficial to other faculty at [redacted] or at another institution.

5. WHAT ARE MY RISKS OF BEING IN THIS STUDY?

Because of the small number of participants, there is some risk that you may be identified as a participant of this study. Your participation in this study is strictly voluntary, and you will be under no obligation whatsoever to answer any questions that you are not inclined to answer. You may choose not to answer any specific questions you do not want to answer and still remain in the study.

6. HOW WILL MY PERSONAL INFORMATION BE PROTECTED?

Please note that your responses will be used for research purposes only and will be strictly confidential. Your college will not be able to examine your individual responses. The following procedures will be used to protect the confidentiality of your study records. All electronic files (audio recordings, master key of names and pseudonyms, and digital transcriptions) containing identifiable information will be password protected. Any computer hosting such files will also have password protection to prevent access by unauthorized users. Only the members of the research staff will have access to the passwords. Any transcribed notes will be kept in a locked file cabinet. At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations. The master file and audio files will be destroyed 3 years after the close of the study.

7. WILL I RECEIVE ANY PAYMENT FOR TAKING PART IN THE STUDY?

There is no payment for taking part in this study. Participants will be eligible to enter a free draw to receive one iPad mini. There is no cash alternative or substitution. To qualify, participants must complete the informed consent before 3/12/2016 however; completing the study is not required. Each participant will be automatically entered and receive one chance in the free draw as all participants are weighted equally. The winner will be drawn with a third-party witness present and be notified via their official [redacted] e-mail address on May 27, 2016. The winner must claim their prize by 9/1/2016. These policies were developed using the Market Research Society Regulations for Administering Incentives and Free Prize Draws (2012).

8. WHAT IF I HAVE QUESTIONS?

If you have further questions about this project or if you have a research-related problem, you may contact the researcher, Bradford Wheeler at bdwheele@umass.edu or 978-618-1198 or you may contact faculty sponsor Dr. Torrey Trust at torrey@umass.edu or 413-545-1574. If you have any questions concerning your rights as a research subject, you may contact Associate Dean for Academic Affairs Dr. Linda L. Griffin at lgriffin@educ.umass.edu or 413- 545-6985. If you have any questions concerning your rights as a research subject, you may contact the University of Massachusetts Amherst Human Research Protection Office (HRPO) at 413-545-3528 or humansubjects@ora.umass.edu.

9. CAN I STOP BEING IN THE STUDY?

You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you may drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate.

SUBJECT STATEMENT OF VOLUNTARY CONSENT

By agreeing, I am voluntarily entering this study. I have had a chance to read this consent information, and it was explained to me in a language which I use and understand. I have the opportunity to contact the researcher via e-mail at bdwheele@umass.edu or by phone 978-618-1198 if I have any questions. By clicking “I agree” below I am indicating that I am at least 18 years old, have read and understood this consent form and agree to participate in this research study. Please print a copy of this page for your records.

- I agree
- I do not agree

APPENDIX E:

INSTRUMENT: PRE-TEST SURVEY

Q1.1 (Informed consent – see Appendix D)

Q2.1 Instructor Information Spring 2016

Q2.2 What is your gender?

- I identify as male
- I identify as female
- I identify as trans-gender
- None of the above
- I prefer not to say

Q2.3 Select your rank

- Full Professor
- Associate Professor
- Assistant Professor
- Senior Lecturer II
- Senior Lecturer
- Lecturer
- Adjunct Faculty
- Graduate Teaching Assistant (TA/TO)
- Emeritus
- Other

Q2.4 Years of college level teaching experience

Q2.5 Average number of courses taught per semester over past 3 years

Q2.6 Number of TBL classes you've taught since 2011

Q2.7 What classroom do you use to teach ALC in Spring 2016

- ILC N111
- ILC S110
- ILC S120
- ILC S220
- ILC S311
- Other (please describe) ____________________

Q2.8 Select technology platforms you use regularly

- *Computer - Microsoft Windows
- *Computer - Apple OSX
- *Computer - Linux (Ubuntu, etc.)
- *Mobile - Apple's iOS (iPhone/iPad)
- *Mobile - Google Android (Mobile Phone)
- *Other ____________________
- *Other ____________________

Q3.1 TBL Technology Tools & Use

In this section, each item requires an answer on two columns. The first column asks you to rate the importance of that item for TBL instruction and the second column asks you to rate how frequently you use it in Spring 2016.

	How important is the tool for TBL Instruction? Not Important | Unsure | Important	How often do you use the tool? Never | Sometimes | Often
Podium classroom control [see image]		
Handheld classroom control [see image]		
Podium connectors (VGA or HDMI cords) [see image]		
Your own (or college) personal laptop		
Your own mobile phone		
Your own (or college) tablet		
Lectern computer [see image]		
Lectern document camera [see image]		

Instructor microphone (handheld or clip-on) [see image]		
iClickers [see image]		
Stadium LCD monitors [see image]		
Wall mounted LCD T's [see image]		
Classroom DVD player [see image]		
Apple TV OR Wireless Projection System [see image]		
Echo 360 Lecture Capture [see image]		
Benchmark 3000 classroom scoring system [see image]		
Student - personal laptops		
Student - mobile phones		
Student table - classroom laptops [see image]		
Student table - connectors (VGA or HDMI cords) [see image]		
Student table - microphones [see image]		
Student table - CALL button [see image]		
Student table - whiteboard [see image]		
Student table - whiteboard camera [see image]		
Student table - wall buttons [see image]		
Other (please specify)		
Other (please specify)		

Q4.1 Barriers that Limit Faculty Use of Technology for ALC Instruction

Please indicate the extent to which each of the following barriers limit your use of technology for ALC instruction in Spring 2016.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Lack of technology equipment					
Lack of software					
Lack of time					
Lack of opportunities to learn how to use technology for ALC instruction					
Lack of effective training in ALC technology					
Lack of technical support in classroom					
Lack of administrative support					
Lack of collegial support and interaction at the University					
Lack of confidence in using the ALC technologies					
Lack of personal interest in ALC technologies					
Reduced ALC course quality					
Are there any other barriers that have limited your use of technology for ALC instruction? (please specify)					
Are there any other barriers that have limited your use					

of technology for ALC instruction? (please specify)					

Q5.1 Attitudes about Active Learning Classroom Technology as a Tool for Instruction

Please rate the following items according to how you agree or disagree with each statement for Spring 2016

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My ALC instruction is more effective with the use of Active Learning Classroom technology					
The use of Active Learning Classroom technology makes learning more interesting					
Active Learning Classroom technology makes it easier to deliver content					
I feel comfortable using Active Learning Classroom technology for instruction					
I feel comfortable playing around with technology tools I am not familiar with					
I have access to more resources with the use of Active Learning Classroom technology					
Technology tools can be used to represent complex concepts in Active Learning Classrooms					

The use of technology makes learning less social in an Active Learning Classroom					
The use of Active Learning Classroom technology can distract students from learning					
I feel uneasy using Active Learning Classroom technology tools I am not familiar with					

Q6.1 Consultation Support

What challenges are you currently facing in your classroom?

Q6.2 In the future, what would you like to do with Active Learning Classroom technology?

Q6.3 What classroom technologies do you want to learn more about?

Q7.1 Additional Comments

Please describe anything else about ALC technology barriers and adoption not addressed in this survey.

APPENDIX F:

INSTRUMENT, ACTIVE LEARNING CLASSROOM OBSERVATION TOOL

Adapted from ISTE Classroom Observation Tool (ICOT), 2013 & Karabulut Igu, 2013

1. Setting

Date	Program	Participant	Class	# of Students

Observation Start Time	
Observation End Time	

2. Classroom Characteristics

3. Student Groupings (check if pedagogical technique used during class)

Ind. work	Pair Work	Small Groups	Entire Class	Other

4. Teacher Roles (check if observed during class)

Lecture	Inter. Disc.	Facility/Coaching	Modeling	Other

5. Learning Activities & Topics

6. How essential was technology to the teaching and learning activities?

- Not needed; other approaches would be *better*
- Somewhat useful; other approaches would be as *effective*
- Useful; other approaches would *not be as effective*
- Essential; the lesson could not be done without it.

Comments:

7. Technologies Used

Active Learning Classroom Technology Tool	Teacher's Use	Student Use (requested)	Notes
Podium classroom control			
Handheld classroom control			
Podium connectors (VGA/HDMI)			
Instructor - personal laptop			
Instructor - mobile phone			
Instructor - tablet			
Lectern computer			
Lectern document camera			
Instructor mic (handheld or clip-on)			
iClickers			
Stadium LCD monitors			
Wall mounted LCD TV's			
Classroom DVD player			
Apple TV or WPS			
Echo 360 Lecture Capture			
Benchmark 3K scoring system machine			
Student - personal laptops			
Student - mobile phone			
Student table - classroom laptops			
Student table - connectors (VGA/HDMI)			
Student table – microphones			
Student table - CALL button			
Student table - whiteboard			
Student table - whiteboard camera			
Student table – wall buttons			

Other (_________________)			
Other (_________________)			

8. Time Chart

3-Minute Chart

Pre-Class Notes	Technology is:	-10 min	-9	-8	-7	-6	-5	-4	-3	-2	-1	00
	In use by students											
	Used for learning											
	In use by teacher											
	Used for learning											

Technology is:	3 min	6	9	12	15	18	21	24	27	30	33	36	39	42	45
In use by students															
Used for learning															
In use by teacher															
Used for learning															

Technology is:	48 min	51	54	57	60	63	66	69	72	75	78	81	84	87	90
In use by students															
Used for learning															

In use by teacher															
Used for learning															

APPENDIX G:

INSTRUMENT, ACTION RESEARCH - CONSULTATION I OF II

MEET IN ACTIVE LEARNING CLASSROOM [“HANDS-ON” IN-SITU EXPERIENCE]

1. Background & Warm-up Questions
   a. Discuss general teaching experience
   b. What inspired you to teach in an Active Learning Classroom?
   c. Describe your experience transitioning your course from traditional to student-centered pedagogy.

Technology

. Discuss what it was like to first use the Active Learning Classroom technology(ies)

a. What classroom technology(ies) have worked well in your class and why?

b. Describe any challenges you’ve experienced when using a particular Active Learning Classroom technology(ies)? If so, please describe the experience you faced.

Pre-Survey Review – Linking to Barriers & Adoption

. Let’s turn to your online survey, specifically the question about Active Learning Classroom technology tools. Let’s focus on the question that lists each classroom tool, how often you use them and how important they are for your class

i. Sub-questions
   1. Why or how did you choose these?
   2. Why did you opt not to use X technology?

a. Sub-questions

i. Were there other options available?

ii. Do you use any tools in other classes?

a. Let’s turn to your online survey, Active Learning Classrooms are largely built to favor either Windows or Apple operating, could you describe your experience with this setup?

b. Let’s turn to your online survey, specifically the question about Active Learning Classroom technology barriers that you’ve experienced

. Can you describe these in more detail?

i. What resources could help you overcome these barriers?

Consultation Intervention

. Hands-on training: Let's visit the classroom technologies

. Do you have questions about tools?

i. Are there any tools I can demonstrate for/with you?

ii. Let's brainstorm on the whiteboard [or other tool of your choice] ways to use it in your teaching.

a. Let's discuss your future Active Learning Classroom technology goals (see pre-survey comments)

b. Provide participant with Moodle resources on Active Learning Classroom technology tools and resources hosted through Moodle. Inform participant to utilize them and we will discuss how these and today's intervention worked at the next (final) consultation

c. Schedule classroom observation and provide participant with information about classroom observation [handout]

APPENDIX H:

INSTRUMENT, ACTION RESEARCH - CONSULTATION II OF II

MEET IN ACTIVE LEARNING CLASSROOM [“HANDS-ON” IN-SITU EXPERIENCE]

1. Background & Warm-Up
   a. How is your Active Learning Classroom teaching experience proceeding this semester?

   Intervention Follow-up

   . Classroom Observation: Feedback

   i. We had a classroom observation, a classic faculty development tool for providing feedback to instructors. Let’s review the information.

   a. Moodle Resources: Feedback

   . Let’s talk about the online TBL technology resources, how are they working?

   Consultation Intervention

   . Hands-on training: Let’s revisit the classroom technologies

   . Do you have any new questions or thoughts about the tools?

   i. Are there any tools I can demonstrate or remonstrate for/with you?

   ii. Let’s discuss what’s worked and what hasn’t in the classroom.

   iii. Let’s brainstorm on the whiteboard [or other tool of your choice] ways to use it in your teaching.

   a. What additional resources could help you overcome technology barriers?

   b. Do you plan to make any changes to your technology use in future Active Learning Classroom classes that you teach?

   c. Have you faced any challenges when using a particular Active Learning Classroom technology(ies)? If so, please describe the experience you faced.

   . Sub-questions

   1. How did you overcome the challenges?
   2. What would have helped you overcome the challenges more easily (e.g., more support, better training)?

   d. Let’s see if there are additional technology resources available for you.

   Pre-Survey Review – Linking to Barriers & Adoption

   . Let’s revisit your online survey about classroom technology tools – how frequently you use them and how important they are for your class.

   . How has your technology tool use changed? Please describe what brought about or didn’t bring about the changes.

   i. What technology tools do you value differently now? Please describe why and how you view/don’t view them differently.

a. Let’s revisit the barriers you’ve discussed on the survey, and during our first consultation

. Describe how these have changed? Can you give an example?

i. What new barriers that have developed during the semester, OR how have existing barriers changed during the semester?

ii. Can you describe your experience with the classroom observation?

APPENDIX I:

QUANTITATIVE SURVEY INSTRUMENT, POST-TEST

Q1.1 Dear Instructor, This is the final phase of the research study. This survey will ask about your Active Learning Classroom technology experience. It will take you approximately 10 minutes to complete. Thank you –Brad

Q2.1 TBL Technology Tools & Use

In this section, each item requires an answer on two columns. The first column asks you to rate the importance of that item for TBL instruction and the second column asks you to rate how frequently you use it in Spring 2016.

	How important is the tool for TBL instruction? Not Important | Unsure | Important	How often do you use the tool? Never | Sometimes | Often
Podium classroom control [see image]		
Handheld classroom control [see image]		
Podium connectors (VGA or HDMI cords) [see image]		
Your own (or college) personal laptop		
Your own mobile phone		
Your own (or college) tablet		
Lectern computer [see image]		
Lectern document camera [see image]		
Instructor microphone (handheld or clip-on) [see image]		
iClickers [see image]		
Stadium LCD monitors [see image]		
Wall mounted LCD TV's [see image]		

Classroom DVD player [see image]		
Apple TV OR Wireless Projection System [see image]		
Echo 360 Lecture Capture [see image]		
Benchmark 3000 classroom scoring system [see image]		
Student - personal laptops		
Student - mobile phones		
Student table - classroom laptops [see image]		
Student table - connectors (VGA or HDMI cords) [see image]		
Student table - microphones [see image]		
Student table - CALL button [see image]		
Student table - whiteboard [see image]		
Student table - whiteboard camera [see image]		
Student table - wall buttons [see image]		
Other (please specify)		
Other (please specify)		

Q2.1 TBL Technology Tools & Use

In this section, each item requires an answer on two columns. The first column asks you to rate the importance of that item for TBL instruction and the second column asks you to rate how frequently you use it in Spring 2016.

Q3.1 Barriers that Limit Faculty Use of Technology for TBL Instruction

Please indicate the extent to which each of the following barriers limit your use of technology for TBL instruction in Spring 2016.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Lack of technology equipment					
Lack of software					
Lack of time					
Lack of opportunities to learn how to use technology for TBL instruction					
Lack of effective training in TBL technology					
Lack of technical support in classroom					
Lack of administrative support					
Lack of collegial support and interaction at the University					
Lack of confidence in using the TBL technologies					
Lack of personal interest in TBL technologies					
Reduced TBL course quality					
Are there any other barriers that have limited your use of technology for TBL instruction? (please specify)					
Are there any other barriers that have limited your use of technology for TBL instruction? (please specify)					

Q4.1 Attitudes about Active Learning Classroom Technology as a Tool for Instruction

Please rate the following items according to how you agree or disagree with each statement for Spring 2016

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
My TBL instruction is more effective with the use of Active Learning Classroom technology					
The use of Active Learning Classroom technology makes learning more interesting					
Active Learning Classroom technology makes it easier to deliver content					
I feel comfortable using Active Learning Classroom technology for instruction					
I feel comfortable playing around with technology tools I am not familiar with					
I have access to more resources with the use of Active Learning Classroom technology					
Technology tools can be used to represent complex concepts in Active Learning Classrooms					
The use of technology makes learning less social in an Active Learning Classroom					
The use of Active Learning Classroom technology can distract students from learning					
I feel uneasy using Active Learning Classroom technology tools I am not familiar with					

Q5.1 Reflecting on your Experience

Please rate the following items according to how you agree or disagree with each statement for Spring 2016

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
This research study provided specific, practical information on Active Learning Classroom technology					
This research study helped me to overcome barriers to Active Learning Classroom technology					
The first consultation was helpful to me					
The classroom observation was helpful to me					
The second consultation was helpful to me					
The online resources were helpful to me					

Q5.2 What did you enjoy most about this research study?

Q5.3 What parts of the research study could be improved?

Q6.1 Additional Comments

Please describe anything else about TBL technology barriers and adoption or the research study not addressed in this survey.

APPENDIX J:

INSTRUMENT APPROVAL, LEARNING SPACES RESEARCH INSTRUMENTS

From: Bradford Wheeler
Sent: Thursday, October 01, 2015 1:52 PM
To: 'jdwalker@umn.edu'; 'baepl001@umn.edu'
Subject: UMN ALC Instrumentation: Request

Dear J.D. and Paul,

I am a doctoral student from the University of Massachusetts, Amherst. I am conducting a pilot research study tentatively titled "Factors That Influence Faculty of Adoption of Technologies in Team-Based Learning Classrooms" under the direction of my advisor, Dr. Torrey Trust. I would like to learn more about the instrumentation you developed for Active Learning Classrooms. Are you able and willing to share these instruments with me?

Thank you very much, I look forward to hearing from you,
-Brad

Brad Wheeler

Doctoral Student
Mathematics, Science, and Learning Technologies Program
Department of Teacher Education and Curriculum Studies
University of Massachusetts Amherst
College of Education
bdwheele@umass.edu

From: J.D. Walker [mailto:jdwalker@umn.edu]
Sent: Monday, October 05, 2015 2:52 PM
To: Bradford Wheeler; baepl001@umn.edu
Subject: Re: UMN ALC Instrumentation: Request

Hi Brad,
I'm glad you ran across our work, and you're more than welcome to use our measures, either as they stand or in modified form. If you do find them useful, we'd just ask that you please give credit in an appropriate place in your work (like

a footnote) to the Research & Evaluation Team, Center for Educational Innovation, University of Minnesota. The instruments are online at http://z.umn.edu/LSR.

Good luck with your work!

Best,

Walker

APPENDIX K:

INSTRUMENT APPROVAL, ISTE CLASSROOM OBSERVATION TOOL

ISTE International Society for Technology in Education

Connected learning. Connected world.™

November 30, 2015

Bradford Wheeler
Doctoral Candidate
University of Massachusetts - Amherst
[redacted]
bdwheele@umass.edu

Dear Mr. Wheeler:

Thank you for your request for permission to use the ISTE Classroom Observation Tool (ICOT) for your doctoral dissertation for University of Massachusetts – Amherst.

We are pleased to grant you permission to use the ICOT under the following terms:

1. This permission allows you to use the ICOT tool as requested for your dissertation and in all copies to meet university requirements, including University Microfilms edition.

2. This permission is non-transferable. Though this permissions allows you to authorize others to use the ICOT in your data collection activities, it does not authorize others to utilize the ICOT in any projects separate from yours.

3. There will be a standard credit to our material, using the copyright notice information below. We request that you reference the tool and any supporting materials, but do not publish the tool itself as an appendix or in any way including images.

   ISTE Classroom Observation Tool, ©2014, ISTE® (International Society for Technology in Education), iste.org. All rights reserved.

4. In lieu of a fee please have a copy of your dissertation sent to ISTE Attn: Permissions Fulfillment, 180 West 8th Ave. Suite 300 Eugene, OR 97401 (accompanied by a copy of this letter) or digitally to Sarah Stoeckl, sstoeckl@iste.org.

5. No other rights are granted with this request.

Thank you for your interest in the International Society for Technology in Education. Please don't hesitate to contact me if you have any questions.

Sincerely,
Sarah Stoeckl

180 West 8th Ave, Suite 300 Eugene, OR 97401 | 800.336.5191 | iste.org

International Society for Technology in Education

Copyright notices:

Please sign and date below to indicate that you acknowledge and agree to the terms above.

Signature: Bradford D. Wheeler Digitally signed by Bradford D. Wheeler [redacted] Date: 2015.12.0[redacted] Date:_______________

APPENDIX L:

PARTICIPANT INFORMATION

Instructor	Course			Cap	Enrolled
Marie	Perspectives in Nursing			99	88
	This course provides an overview of healthcare services and historical events in nursing. The role of the nurse and patient experience will be introduced.				
Lindsay	Sustainable Living			99	97
	Students will work in teams to research and develop solutions to the sustainable challenges facing our society. They will collaborate to investigate, critically evaluate, effectively communicate, and reflect on the multifaceted challenges associated with addressing sustainable resource use, water, food, energy, transportation, waste management, and climate change. Students will also work in teams during class on exercises in which they research case studies, debate controversies, assess political and cultural contexts, and identify technological advances and barriers, gaps in scientific knowledge, and opportunities for change in the 21st century.				
Daniel	Chemical Engineering			75	73
	An introduction to chemical engineering problem solving methods. Basic chemical engineering principles and their application to chemical processes studied. Concepts include pressure, temperature, volume, heat capacity, and mass and energy balances.				
Hans	Elementary Physical Chemistry			42	38
	An overview of physical chemistry (thermodynamics, kinetics, statistical and quantum mechanics, and spectroscopy) emphasizing applications to biology including macromolecule structure and stability, ligand binding, enzyme catalysis, and membrane structure and transport.				
Mitch	Intro to Physics 1			99	99
	Basic physical laws governing mechanics, heat, and sound; examples and applications from the biological sciences. Arithmetic, high school algebra, and basic trigonometry required. The recommended introductory physics course for majors in the biological sciences and related areas.				

Instructor	Course			Cap	Enrolled
Anderson	Music Theory II			99	58
	Continuation of MUSIC Theory I				
Tim	Highway Location & Geometric Design			99	49
	Highway location and geometric design principles for streets and highways with emphasis on roadway safety. Includes state of the art design policies and current research findings. AutoCAD and transportation design computer software used for class assignments and the class project. Prerequisite: CEENGIN 310				
Alexis	Drama and the Media			63	59
	This course asks students to consider the following questions: How are media constructed and produced? Received and understood? And how do media make meaning in culture? How are the stories and mythologies that circulate in various media (film, TV, print, social media) made "dramatic" or framed by and structured using theatrical techniques? And to what ends? How do social groups perform themselves and others? Locating our study in the cultures of the United States, Middle East, and Africa, and by exploring the connections between "drama" and "media," we will develop our abilities to critically analyze and decode meaning embedded in media texts, consider how nations perform themselves and others using various media, and ultimately become more savvy, ethical media consumers/producers and citizens of our global world				
Chris	Cancer Genetics			66	26
	Description not available				
Tyson	Career and Professional Development			66	50
	This course is designed to prepare students for success in the following career and professional development competencies such as networking, internship/job search, professional etiquette and industry research. Specific activities will include but are not limited to: resume building, interviewing skills, dressing for success, utilizing social media platforms, developing elevator pitches, building professional connections, increasing knowledge of industry and career areas and navigating career fairs.				
Chandler	Community Service with GIST			66	23

Instructor	Course			Cap	Enrolled
	In this course, you will work in teams to design and implement a Web based Open source GIST project for a community organization or [redacted]. In the process, you will learn and understand how the World Wide Web works, the nature of geographic information and how it is processed and visualized on the Web, and the importance of open standards, software, and data. In addition, you will be able to analyze and evaluate possible approaches to geospatial problems. The course is open to all [reacted] students with some computer analytical background, whether GIS or programming or related experience.				
Christi	Electricity & Magnetism			99	61
	Electricity and magnetism. Emphasis on basic foundations of physics and techniques used to solve a wide range of problems. For engineering, math, physics, and other science majors with facility and interest in math and physics.				
Brian	Intro to Physics 1			99	95
	Basic physical laws governing mechanics, heat, and sound; examples and applications from the biological sciences. Arithmetic, high school algebra, and basic trigonometry required. The recommended introductory physics course for majors in the biological sciences and related areas.				

APPENDIX M:

TECHNOLOGY EQUIPMENT FAILURES

Observation 1

Tool(s)	Incident	Resolution
1) Personal Laptop 2) Podium Control 3) LCD TVs	Attempted to project Mac laptop to all screens and it did not work	Connection worked after disconnecting and reconnecting the display and re-pushing content from podium control
1) Whiteboard markers	Asked student tables to write team name on board, notices a lack of markers	Asks TA if they brought markers, and vocalizes a self-reminder to bring markers to future classes
1) Podium Control	Played with podium control while students were working. Looks to researcher “why is my screen blank”	Podium control was “off” researcher turned it on
1) Personal Laptop	Video in PowerPoint fails to load	Pulled up YouTube version of the video via web browser
1) Whiteboard Markers		
1) Podium Control 2) Student Laptop 3) LCD TVs	Instructor has trouble pulling up a student table laptop from the podium controller interface to display on LCD TVs	Instructor walked from the podium, to the team table, back to the podium, and finally over to the wall display once it was complete
1) Student BYOD Laptop	Instructor attempts to troubleshoot class software installation on a student BYOD laptop	Instructor tells student to restart their BYOD laptop
1) LCD TV (A11)	TA informs instructor that table connections are not functioning	None – Instructor says, “A lot of this stuff is still sort of new

Tool(s)	Incident	Resolution
2) Table Connectors	properly for laptops to display to Team LCD	so there are a lot of difficulties”
1) iClicker 2) Personal Laptop 3) Personal Tablet 4) LCD TVs 5) Podium Control	Instructor brought and deployed 10 iClickers. Quiz was displayed to all LCDs, via personal laptop. 11 responses occurred, TA’s struggled to pivot back Personal Tablet onto LCDs using podium control.	Instructor is confused, stops quiz, returns to other teaching instruction.
1) Wall LCD	Table B5 LCD not working	None
1) iClicker	Instructor notices that during 5 iClicker practice quiz questions, the compiled results are in wrong format	Instructor emphasizes that this is a practice quiz, and later recognizes that the submission format was “short answer” not “multiple choice
1) Whiteboard Markers	Instructor answers student question at table A11, proceeds to write on the whiteboard with personal marker, states to the group that markers are generally lacking in the room.	Aborts writing on board with his own marker, returns to podium to describe the equation
1) Wall LCD 2) Student Table Laptop	Table A4 experiences a flickering when projecting to Wall LCD	Instructor informs student to stop touching the technology because it has a technical issue
1) Wall LCD	Table A7 doesn’t accept input, shows static	None
1) Document Camera	Autofocus doesn’t work and instructor questions why	Instructor waits for camera to “wake up” and proceeds

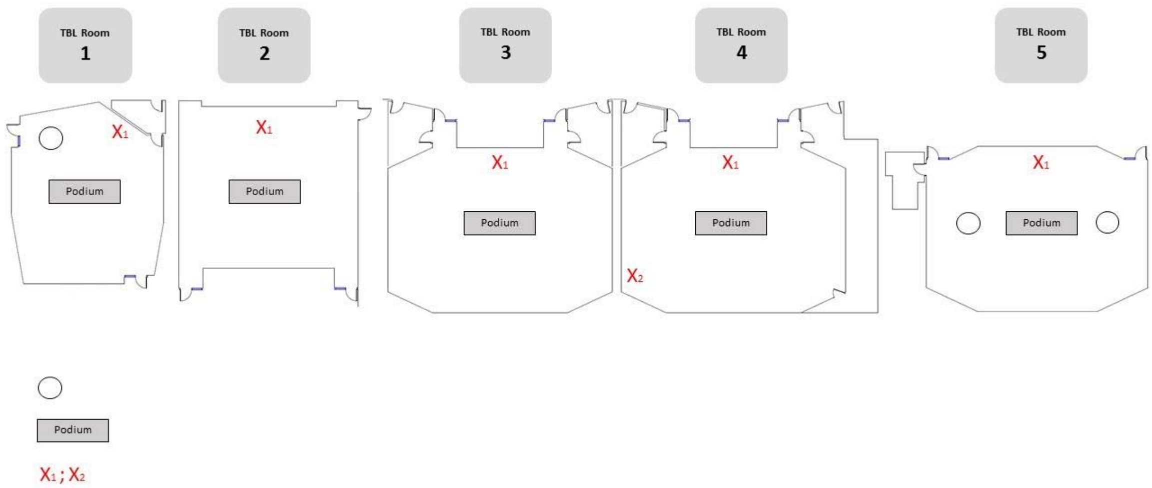
Observation 2

Tool(s)	Incident	Resolution
1) Student Laptop 2) Student Table Connectors 3) LCD TVs 4) Document Camera	Students are unable to connect laptop at student table to present a digital poster, lack of adapters	1) Instructor asks team to move to another team table where they can connect their laptop. 2) Suggests that students could place their laptop on the document camera and project on, then opts to abort this idea and move to a different team.
1) Personal Tablet	Instructor unable to access Microsoft Surface's color panel and eraser, says "this thing isn't working great today"	Pauses and spends a few seconds to toggle the panel and eraser.
1) Student Laptop 2) Student Table Connectors	Students are unable to connect laptop at student table to present a digital poster	Instructor asks student to bring laptop to podium so it can be connected and broadcast from the instructor station
1) Podium Control 2) Instructor Laptop 3) Podium Connectors 3) Student Laptop	Instructor experiences input issue on Podium controller when connecting instructor laptop via HDMI and student laptop via VGA	The Laptop source has a VGA and HDMI input source, the podium control cannot distinguish when both inputs are active on the line. Instructor unplugged student laptop.
1) Document Camera 2) LCD Displays	Document camera doesn't properly display to LCD displays	The document camera was pointing the wrong direction and a student calls out that the camera is angled improperly
1) Personal Tablet	Microsoft Surface keyboard does not behave as expected	Pauses spends a few seconds to properly solve keyboard issue

Tool(s)	Incident	Resolution
1) Personal Tablet 2) LCD TVs	Microsoft Surface tablet displays “runtime error” during PowerPoint Presentation	Instructor reads prompt out loud, clicks “ignore” button and proceeds with lecture
1) Other Equip – Camera 2) Other Equip - Oscillator	Oscillator experiment is setup on a student table and displays improper information that a video camera, plugged into a student table projects to all displays	Instructor pauses lesson, attempts to troubleshoot at the oscillator with no success. Moves to podium and continues lesson while lab technician troubleshoots until the end of class when it was resolved. As class ends, instructor says, ‘they’re not paying attention, but I’ll leave it up”
1) LCD TV	LCD display at table B7 does not work after repeated attempts to push content to it	Instructor attempts multiple times to refresh the screen, walks to screen, checks wiring, returns to laptop station and screen still not working. The issue resolves itself randomly during class with B7 working.

APPENDIX N:

ACTIVE LEARNING CLASSROOM LAYOUTS



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