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Impact of technology-infused interactive learning environments on college professors' instructional decisions and practices

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IMPACT OF TECHNOLOGY-INFUSED INTERACTIVE LEARNING ENVIRONMENTS ON COLLEGE PROFESSORS' INSTRUCTIONAL DECISIONS AND PRACTICES

by

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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

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To my parents, my brother and Suranga

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ABSTRACT

Recent advancements in instructional technology and interactive learning space designs have transformed how undergraduate classrooms are envisioned and conducted today. Large number of research studies have documented the impact of instructional technology and interactive learning spaces on elevated student learning gains, positive attitudes, and increased student engagement in undergraduate classrooms across nation. These research findings combined with the movement towards student-centered instructional strategies have motivated college professors to explore the unfamiliar territories of instructional technology and interactive learning spaces. Only a limited number of research studies that explored college professors' perspective on instructional technology and interactive learning space use in undergraduate classrooms exist in the education research literature. Since college professors are an essential factor in undergraduate students' academic success, investigating how college professors perceive and utilize instructional technology and interactive learning environments can provide insights into designing effective professional development programs for college professors across undergraduate institutions. Therefore, the purpose of this study was to investigate college professors' pedagogical reasoning behind incorporating different types of instructional technologies and teaching strategies to foster student learning in technology-infused interactive learning environments. Furthermore, this study explored the extent to which college professors' instructional decisions and practices are affected by teaching in an interactive learning space along with their overall perception of instructional technology and interactive learning spaces.

Four college professors from a large public Midwestern university who taught undergraduate science courses in a classroom based on the 'SCALE-UP model' participated in this study. Major data sources included classroom observations, interviews and questionnaires. An enumerative approach and the constant comparative method were utilized to analyze the data. According to the results obtained, all the participating college professors of this study employed a variety of instructional technologies and learning space features to actively engage their students in classroom activities. Participants were largely influenced by the instructional technology and the learning space features at lesson planning and execution stages whereas this influence was less notable at the student assessment stage. Overall, college professors perceive technology-infused interactive learning environments to be advantageous in terms of enabling flexibility and creativity along with easy facilitation of classroom activities. However, they felt challenged when designing effective classroom activities and preferred continuous professional development support. Overall, college professors' pedagogical decision making process, their perceived benefits and challenges seemed to be interrelated and centered on the learners and the learning process.

Primary implication of this study is to implement effective professional development programs for college professors which enable them to familiarize themselves with student-centered pedagogy and effective classroom activity design along with the novel trends in learning space design and instructional technologies. Furthermore, higher education institutions need to devise incentives and recognition measures to appreciate college professors' contributions to advance scholarship of teaching and learning.

PUBLIC ABSTRACT

Recent advancements in instructional technology and interactive learning space designs have transformed how undergraduate classrooms are conducted today. A large number of research studies have documented the positive impacts of these innovative instructional strategies on student learning gains and student engagement. Since college professors are an essential factor in undergraduate students' academic success, investigating how college professors perceive and utilize these innovative instructional strategies can provide insights into designing effective professional development programs. Therefore, the purpose of this study was to explore the extent to which college professors' instructional decisions and practices are affected by teaching in an interactive learning space. Four college professors from a large public Midwestern university who taught undergraduate science courses in a classroom based on the 'SCALE-UP model' participated in this study. Major data sources included classroom observations, interviews and questionnaires. A constant comparative method was used to identify the common patterns that emerged from the data.

Findings of this study showed that all four college professors employed a variety of instructional technologies and learning space features such as team-based learning, inquiry-guided learning, and hands-on learning to actively engage their students in classroom activities. Overall, college professors perceive technology-infused interactive learning environments to be advantageous in terms of enabling flexibility and creativity along with easy facilitation of classroom activities. However, they felt challenged when designing effective classroom activities and preferred continuous professional development support. Furthermore, college professors revealed the value of being

recognized by their colleagues for their involvement in advancing the scholarship of teaching.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Chapter one provides a brief introduction to this research study. Section 1.1 presents the background information concerning the study. Sections 1.2, 1.3 and 1.4 state the purpose, research questions and rationale for this research work respectively. Section 1.5 concludes the chapter with the scholarly significance of this study.

1.1 Background

Recent developments in technology have revolutionized the society we live in; from our basic needs to complex activities that we engage in as humans are shaped by these technological advancements (Jones, et al., 2008; Metzger et al., 2003; Vedantham & Hassen, 2011). Today's undergraduate students are very much comfortable as consumers of technology. They show a significant increase in using various technological aspects such as online-libraries, web-based course instruction, learning tools, and the other World Wide Web applications to negotiate many aspects of their academic lives (Jones, et al., 2008; Metzger et al., 2003). Looking back at the past few decades, the historical view of the 'classroom' has dramatically changed (Oblinger, 2005). The main reason behind this change can be attributed to the superior communication ability of the Internet. Distant learning courses, online-homework programs, online lectures, digital access to course materials, and digital submission of assignments are remarkably common, thus the 'classroom' is no longer just a physical space (Miller et al., 2000; Oblinger, 2005). Furthermore, enrollments in introductory course have increased over time so that providing access to resources such as course materials are more convenient with digital technology (Georgiana & Hosford, 2009; Oblinger, 2005). To fulfill these demanding needs, higher education institutions have adopted digital infrastructures to support both instructional technology and student learning technology (Georgiana & Hosford, 2009; Handelsman et al., 2004; Henderson et al., 2011). Moreover, progression towards constructivist pedagogy combined with research findings in educational

psychology and cognition have given rise to student-centered instructional strategies such as collaborative learning, team-based learning, project-based learning etc. that have yielded elevated student learning gains (Handelsman et al., 2004; Henderson et al., 2011; Par & Choi, 2014). As a result, the traditional views of 'classroom' and 'teaching' have seen significant changes in order to accommodate these instructional strategies, which once again include a variety of digital technologies and interactive learning space designs such as SCALE-UP classrooms. Increasing amounts of resources such as public and private funding, IT personnel and resources, teaching and learning centers, and national conferences and workshops have been dedicated towards designing novel instructional strategies and learning spaces (Beichner, 2006; Handelsman et al., 2004; Henderson et al., 2011; Hooper & Rieber, 1995; Gaffney et al., 2008; Major & Palmer, 2006; Oblinger, 2005). Ultimately, these factors collectively require college professors' to embrace novel instructional strategies and practices and incorporate technology and interactive learning approaches in their classrooms.

Two main methods of integrating technology into undergraduate classrooms were observed during past decade: (1) construction of technology-infused learning spaces such as SCALE-UP classrooms (Beichner, 2006; Gaffney et al., 2008; Brooks, 2011; Van Horne et al., 2012; Cotner et al., 2013; Florman, 2014) and (2) development of technological learning-tools such as subject specific software designs, web-based software designs, and mobile apps that aid student learning (Amaral et al., 2013; Charlesworth & Vician, 2003; Dancy, 2006; Dori et al., 2007; Ellis, 2013; Enriquez, 2010; Jones, 2013; Libman & Huang, 2013; Muthyala & Wei, 2012; Warnakulasooriya et al., 2005).

A considerable amount of educational research literature can be found regarding the vision and implementation of several interactive learning spaces across universities in the nation (Beichner, 2006; Brooks, 2011; Brown & Lippincott, 2003; Cotner et al., 2013; Florman, 2014; Gaffney et al., 2008; Handelsman et al., 2004; Van Horne et al., 2012;

Oblinger, 2005). The research literature also highlights the pedagogical consequences of reforming traditional classrooms to technology-infused learning spaces. For example, technology-infused interactive learning spaces enable the efficient use of student-centered instructional strategies such as active, team-based, peer-led, and inquiry-guided learning in undergraduate courses (Beichner, 2006; Brooks, 2011; Brown & Lippincott, 2003; Cotner et al., 2013; Florman, 2014; Gaffney et al., 2008; Handelsman et al., 2004; Van Horne et al., 2012; Oblinger, 2005).

Similarly, the education research literature concerning instructional technology describes a variety of learning tools that can provide hands-on learning opportunities for students. These learning tools enable the comprehension of difficult, abstract concepts specifically with respect to STEM disciplines (Amaral et al., 2013; Charlesworth & Vician, 2003; Dancy, 2006; Dori et al., 2007; Ellis, 2013; Enriquez, 2010; Jones, 2013; Libman & Huang, 2013; Muthyala & Wei, 2012; Warnakulasooriya et al., 2005).

Research studies concerning the implementation of various technology-infused learning spaces and instructional technologies reported the following positive impacts: elevated student learning gains, positive attitudes towards subject matter and learning, increased engagement with course materials, and increased student-student and instructor-student interaction in classrooms (Amaral et al., 2013; Beichner, 2006; Beichner et al., 2007; Brooks, 2011; Cotner et al., 2013; Florman, 2014; Freeman et al., 2014; Gaffney et al., 2008; Handelsman et al., 2004; Van Horne, 2012; Muthyala & Wei, 2012; Park & Choi, 2014; Whiteside et al., 2010). In addition, there is substantial empirical evidence that higher education institutions in which the faculty members create an environment that emphasizes active learning strategies and effective educational practices have a dramatic effect on undergraduate students' learning gains and experience (Bonwell & Sutherland, 1996; Chen et al., 2008; Faust & Paulson, 1998; Umbach & Wawrzynski, 2005). In a research study investigating the factors affecting undergraduate students' class participation, Fassinger (1995) reported that college professors' ability to

create courses and class activities that foster positive emotional climates directly impact interactions among students. Similarly, using two national data sets, Umbach & Wawrzynski (2005) found that students reported higher levels of engagement and learning at institutions where faculty members use active and collaborative learning techniques to engage students in learning experiences, and to emphasize higher-order cognitive activities in the classroom. Furthermore, in an engineering education research study, Chen et al. (2008) reiterated the same findings while stating that engineering faculty members' engagement in the teaching and learning functions of their programs affected the quality of student experience in developing, facilitating, and sustaining high levels of student engagement.

However, the number of research studies that particularly explored college professors' perspectives on instructional technologies and interactive learning space designs is limited (Brown et al., 2004; Felder & Brent, 1996; Grasha & Yangarber-Hick, 2000; Van Horne et al., 2014; McKeachie, 1990; Miller et al., 2000). Technology alone does not enhance teaching; successful integration is all about the ways in which technology tools are used and integrated into teaching. Consequently, this notion indicates that successful integration of technology, learning space, and pedagogy is a critical topic that should be addressed in professional development programs (Grasha & Yangarber-Hick, 2000; McKeachie, 1990; Miller et al., 2000; Georgiana & Hosford, 2009). In this regard, additional research findings and evidence are needed to generate a holistic understanding about how college professors incorporate novel technologies and learning space design into their class sessions and what types of decisions and rationales are behind these choices. Furthermore, outcomes of this study can be used to fill the gaps in the existing educational literature regarding college professors' perception of technology-infused interactive learning environments in terms of benefit, challenges, and desired support. Ultimately, the information gathered from this study can be used to

enhance the existing educational research literature and better inform faculty professional development programs.

1.2 Research purpose

As stated above, college professors in the modern age cannot detach themselves from instructional technological advancements as these advancements are tightly woven to the social and cultural backgrounds of their students and the institutions they teach in. Successful college professors are able to identify effective student-centered teaching strategies and instructional technologies to promote their students' learning. In order to accomplish this, college professors need to be equipped with appropriate knowledge bases and resources that will enable them to make effective instructional and technological decisions.

The purpose of this study is to explore college professors' perceptions of instructional technology use and the extent to which their instructional decisions and practices are affected by teaching in interactive learning spaces. This study also aims to investigate the different types of instructional technologies, learning space features, and novel teaching strategies college professors use to foster student learning, as well as their rationales for employing them. Furthermore, the findings and insights gained will be used to better inform the implementation of beneficial professional development workshops and support programs for college professors.

1.3 Research questions

The following three research questions were formulated in order to achieve the above research purpose:

1. What aspects of the learning environment and available technologies in technology-infused interactive learning spaces do college professors use and what are their pedagogical reasonings behind them?

2. How do technology-infused interactive learning environments influence college professors' instructional decisions and practices at the following stages: lesson planning, lesson execution, and student assessment?
3. What are college professors' perceptions of technology-infused interactive learning environments in terms of benefits, difficulties, and desired support?

1.4 Rationale

Recent advancements in instructional technologies and interactive learning space designs have revolutionized the way undergraduate classrooms are conducted across higher education institutions today. Therefore, as described above, students' expectations for technology use, availability of various technological resources, changes in institutional infrastructure, advancements in educational research, and movement towards student-centered paradigms combine to move college professors to incorporate instructional technologies and innovative instructional strategies in their classrooms (Beichner et al., 2007; Handelsman et al., 2004; Jones, et al., 2008; Metzger et al., 2003; Oblinger, 2005).

A large number of research studies concerning successful implementations of various technology-infused learning spaces and instructional technologies across universities can be found in the education literature. These research studies have also documented a multitude of positive impacts of instructional technology and interactive learning spaces on students' learning gains, attitudes, and engagement in undergraduate classrooms (Beichner, 2006; Beichner et al., 2007; Gaffney et al., 2008; Whiteside, 2010; Brooks, 2011; Van Horne, 2012; Muthyala & Wei, 2012; Cotner et al., 2013; Amaral et al., 2013; Florman, 2014; Freeman et al., 2014). These research findings combined with recent technological advancements necessitate college professors to explore the unfamiliar territories of instructional technology and interactive learning spaces.

Despite the large number of research studies that explored the 'student-perspective' on instructional technology and interactive learning spaces, very few

research studies have explored the 'instructor-perspective' on the matter. For instance, the research literature concerning college professors' perceptions of instructional technologies, interactive learning spaces, and student-centered pedagogy is limited (Brown et al., 2004; Felder & Brent, 1996; Georgina & Olson, 2008; Grasha & Yangarber-Hick, 2000; Van Horne et al., 2014; McKeachie, 1990; Miller et al., 2000) when compared to the research literature concerning K-12 teachers' perceptions of such aspects (Archambault & Crippen 2009; Ertmer & Ottenbreit-Leftwich, 2010; Harris et al., 2009; Hew & Brush, 2007; Hofer & Grandgenett, 2012, Jang & Chen, 2010; Karchmer, 2011; Khan, 2011; Koehler et al., 2007; Koehler & Mishra, 2009; Kramaski & Michalsky, 2010; Lawless & Pellegrino, 2007; Niess, 2005; Russell et al., 2003; Schmidt et al., 2009). Findings from the K-12 literature indicate that teachers' perceptions of novel instructional strategies and technologies include several factors such as self-efficacy, teacher pedagogical beliefs, and school culture, etc. Following these findings, researchers have recommended modifications to existing professional development plans, to incentives within school cultures, to pre-service teacher programs to help teachers better accommodate novel instructional strategies and technologies in their classrooms (Archambault & Crippen 2009; Ertmer & Ottenbreit-Leftwich, 2010; Harris et al., 2009; Hew & Brush, 2007; Hofer & Grandgenett, 2012, Jang & Chen, 2010; Karchmer, 2011; Khan, 2011; Koehler et al., 2007; Koehler & Mishra, 2009; Kramaski & Michalsky, 2010; Lawless & Pellegrino, 2007; Niess, 2005; Russell et al., 2003; Schmidt et al., 2009).

As mentioned in section 1.1, faculty members' attitudes, beliefs, decisions, and actions that emphasize active learning strategies and effective educational practices 'do matter' in undergraduate students' academic success (Bonwell & Sutherland, 1996; Chen et al., 2008; Fassinger, 1995; Faust & Paulson, 1998; Umbach & Wawrzynski, 2005). Furthermore, major concerns relating to the need for faculty to develop a conceptual rationale for using novel technologies and instructional strategies can be seen in the

educational research literature (Georgiana & Olson, 2008; Georgiana & Hosford, 2009; Grasha & Yangarber-Hick, 2000). These concerns refer to how faculty members devise a rationale for the technology incorporation that fits with their teaching philosophy, their beliefs, their learners etc.

In order to resolve these concerns, additional research studies that particularly address college professors' perceptions of instructional technologies and interactive learning space designs need to be carried out. Findings from such research studies can help generate a more complete picture of 'instructor-student teaching-learning dynamics' in higher education institutions. Existing studies on college professors' perceptions of instructional technologies and interactive learning spaces suggest that college professors primarily view these aspects to be beneficial. However, college professors have expressed a desire for professional assistance in terms of meaningfully integrating content, pedagogy, learning space and technological tools in their courses (Brown et al., 2004; Felder & Brent, 1996; Grasha & Yangarber-Hick, 2000; Van Horne et al., 2014; McKeachie, 1990; Miller et al., 2000). Hence, it is of vital importance that college professors are equipped to identify and promote the benefits of instructional technologies and interactive learning spaces while diminishing their obstructions. Further, exploring how college professors make decisions regarding the utilization of certain instructional technologies and strategies can provide insights into how to design effective professional development programs for faculty members across undergraduate institutions. Additionally, findings and insights gained from this study can strengthen the knowledge bases of college professor cognition, student-centered instruction and innovative instructional strategies, faculty professional development, and curriculum reform movements at post-secondary level. Ultimately, the better informed college professors are concerning their innovative instructional strategies, the better they contribute to students' learning gains.

1.5 Significance of the study

Given the positive impact of interactive learning space designs on undergraduate students' learning gains along with the current trend to design more of such learning spaces in universities across the nation, there is an impetus for more college professors to engage themselves in utilizing a variety of interactive teaching strategies in their courses. Furthermore, the role of instructional technologies such as web-based simulations and software programs as effective learning aids for undergraduate students also encourage college professors to employ variety of instructional technologies in their classrooms.

By exploring college professors' perception of instructional technologies and interactive learning spaces along with their expectations for such aspects, we can obtain important insights into the implementation of effective professional development and support programs across undergraduate institutions. For instance, outcomes of this study can assist in revealing college professors' familiarity of learner-centered paradigms, novel trends in instructional strategies, and their motivations for engaging in innovative teaching practices. Moreover, the results of this study can inform us about the difficulties and challenges these college professors' face as they adopt novel teaching practices and instructional technologies in their classrooms.

This study also contributes to enhancing the innovative ways that science education in undergraduate institutions is envisioned to reform and change. Findings of this study can contribute to the knowledge base of instructional technology and technology-infused learning spaces of college science teaching and learning communities which includes college professors, departmental administrators, teaching-center professionals, and fellow researchers. The finding of this study will continue to inspire the higher education community to recognize and appreciate innovative instructional strategies, learning spaces, and instructional technology designs by strengthening, sharing, and validating the scholarly work of the college science teaching community. Ultimately, with the effectiveness of the informed professional development programs, college professors' will be able to incorporate innovative instructional strategies and

technologies to promote student motivation and engagement in undergraduate classrooms.

CHAPTER 2

LITERATURE REVIEW

Chapter two consists of a review of existing literature on innovative instructional strategies, particularly highlighting instructional technologies and interactive learning space designs. Following that, constructivism is discussed as the theoretical framework for this study. Lastly, chapter two is concluded with a compilation of the existing literature on faculty perceptions and professional development concerning instructional technologies and innovative teaching strategies, and identification of the knowledge gaps in this area of the study.

2.1 Innovative instructional strategies in post-secondary education

Teaching itself is a highly complex activity (cognitive skill) which requires many types of knowledge bases (McKeachie, 1990; Kleickmann et al., 2012). These knowledge bases include content knowledge (conceptual and theoretical frameworks of the subject matter to be taught) and pedagogical knowledge (understanding of instructional practices, student learning and assessment strategies, learner characteristics and classroom management) (Kleickmann et al., 2012). However, teaching gets further complicated by the introduction of technology to the classroom. (Grasha & Yangarber-Hick, 2000; Miller et al., 2000; Brown et al., 2004; Koehler et al., 2007; Koehler & Mishra, 2009; Harris et al., 2009; Schimidt et al., 2009; Jang et al., 2010; Angeli & Valandies, 2013).

2.1.1 Instructional technology

Educational researchers are divided as to what role technology plays in teachers'/college professors' knowledge base. On one hand, some researchers argue that technology is merely a tool for accomplishing teaching and learning goals for instructors and students (Grasha & Yangarber-Hick, 2000; Miller et al., 2000). Others have extended the Shulman's formulation of pedagogical content knowledge (PCK) to incorporate technology into teachers' knowledge base hence generating a special knowledge base known as Technological Pedagogical Content Knowledge (TPCK) (Koehler et al., 2007;

Koehler & Mishra, 2009). However, educational researchers collectively agree that merely introducing technology to the classroom without proper understanding of the underlying theoretical frameworks is not productive (Grasha & Yangarber-Hick, 2000; Miller et al., 2000; Brown et al., 2004; Koehler et al., 2007; Koehler & Mishra, 2009; Angeli & Valandies, 2013).

One shortcoming of technology use itself is that, misuse of technology in a classroom can suppress or hinder student learning (Grasha & Yangarber-Hick, 2000; Koehler et al., 2007; Koehler & Mishra, 2009). Therefore, instructors need to think about the relevance or appropriateness of using a particular technology in their classroom so that students are manipulating ideas rather than simply manipulating the technological tools (Brown et al., 2004). Thus, a successful professional development model should include not only methods for helping instructors use technology, but a system for helping the instructor plan learning activities that take advantage of the tools in technology-infused classrooms (Grasha & Yangarber-Hick, 2000; Miller et al., 2000; Van Horne et al., 2012; Florman, 2014). For these professional development programs to be successful, education researchers must gather information about how college professors use the learning environment and available technologies along with their reasoning behind these decisions.

2.1.2 Technology-infused interactive learning space designs

One of the major accommodations of technology in educational settings can be observed in the development of technology-infused learning environments in universities. Some examples of technology-infused classrooms can be found in Massachusetts Institute of Technology's 'Technology Enabled Active Learning' (TEAL) classrooms, North Carolina State University's 'SCALE-UP' classrooms, University of Minnesota's 'Active Learning Classrooms' (ALCs) and University of Iowa's 'Transform-Interact-Learn-Engage' (TILE) classrooms (Beichner, 2006; Gaffney et al., 2008; Brooks, 2011; Van Horne et al., 2012; Cotner et al., 2013; Ingram et al., 2013; Florman, 2014).

According to the constructivist perspective, new knowledge arises out of an individual's active construction of knowledge. Using this viewpoint, it is important to create a learner-centered environment in order to provide opportunities for learners to construct their own knowledge (Cooper 1995; Schuh, 2003). Such learning environments promote active learning *via* cooperative/collaborative learning, peer learning, team-based learning, hands on learning, projects based learning, inquiry-guided learning etc. (Springer et al., 1999; Barak & Dori, 2005; Beichner, 2006; Michalesen & Sweet, 2008; Gaffney, et al., 2008; Van Horne, et al., 2012; Lee, 2012; Cotner, et al., 2013; Florman, 2014).

A large number of research studies regarding the development and impact of technology-infused learning spaces can be found in the educational literature particularly during the last few years (Beichner, 2006; Gaffneyet al., 2008; Michalesen & Sweet, 2008; Brooks, 2011; Van Horne et al., 2012; Cotner et al., 2013; Florman, 2014; Freeman et al., 2014). The theoretical base for the development of these learning spaces can be multifaceted. For example, redesigning traditional classrooms to technology infused learning spaces facilitates inquiry-guided, team-based active learning (Gaffney et al., 2008; Florman, 2014). This realization is achieved *via* the design of the classroom itself. According to many research studies, technology-infused learning spaces provide evidence of improved student learning gains in STEM disciplines (Beichner, 2006; Springer et al., 1999; Brooks, 2011; Cotner et al., 2013). These classroom spaces eliminate the constraints (in terms of pedagogically and technologically) that otherwise limit the college professors' ability to implement novel teaching strategies to facilitate student learning (Beichner, 2006; Gaffney et al., 2008; Brooks, 2011; Cotner et al., 2013; Florman, 2014). Components of these learning spaces include round tables with movable chairs around them, white board space for each table, multiple projectors, TV monitors and screens, laptop computers with internet connection and audio-visual communication systems for the room (Beichner, 2006; Gaffney et al., 2008; Brooks, 2011; Cotner et al., 2013). As shown in Figure 2-1, the main difference in these classrooms is the absence of

a "front" and the presence of "small-groups" when compared to a traditional classroom. Research studies on student learning in technology-infused classrooms have revealed that students gained significantly better conceptual understanding and exhibited better retention of the material. These classrooms had positive influences on student attitudes towards subject matter, learning goals, and classroom dynamics that ultimately led to positive impacts on student achievements (Beichner, 2006; Gaffney et al., 2008; Van Horne et al., 2012; Cotner et al., 2013; Florman, 2014).

2.1.3 Technology-assisted learning tools

Computer related software, web-based applications and simulations developed in various fields of sciences are becoming popular teaching and learning tools among instructors and students (Charlesworth & Vician, 2003; Warnakulasooriya et al., 2005; Dancy, 2006; Dori et al., 2007; Enriquez, 2010; Muthyala & Wei, 2012; Libman & Huang, 2013; Amaral et al., 2013; Jones, 2013; Ellis, 2013). These technological tools are replacing textbooks with e-books and drawings with simulations. Use of such computer-based resources are becoming increasingly popular in science laboratory courses, including automated instrumentation, molecular modeling and simulation software, digitized data collections, data interpretation and graphing applications (Jones, 2013). Similar developments can be seen for supporting student learning in the lecture and for independent study including video demonstrations and animations of otherwise static science concepts, web-based problem solving systems (Mastering Chemistry, Mastering Physics etc. from PEARSON) and more recently, mobile apps for portable devices (e.g. ChemDoodle, ACS mobile, GeneticCode, AA (amino acid) Tutor, Molecular viewer 3D etc. (Warnakulasooriya et al., 2005; Libman & Huang, 2013). Web-based instructional designs are developed to align with the cognitive development of the students. These applications help students to learn and understand the concepts at their own pace by providing immediate feedback in terms of hints and suggestions (Jones,

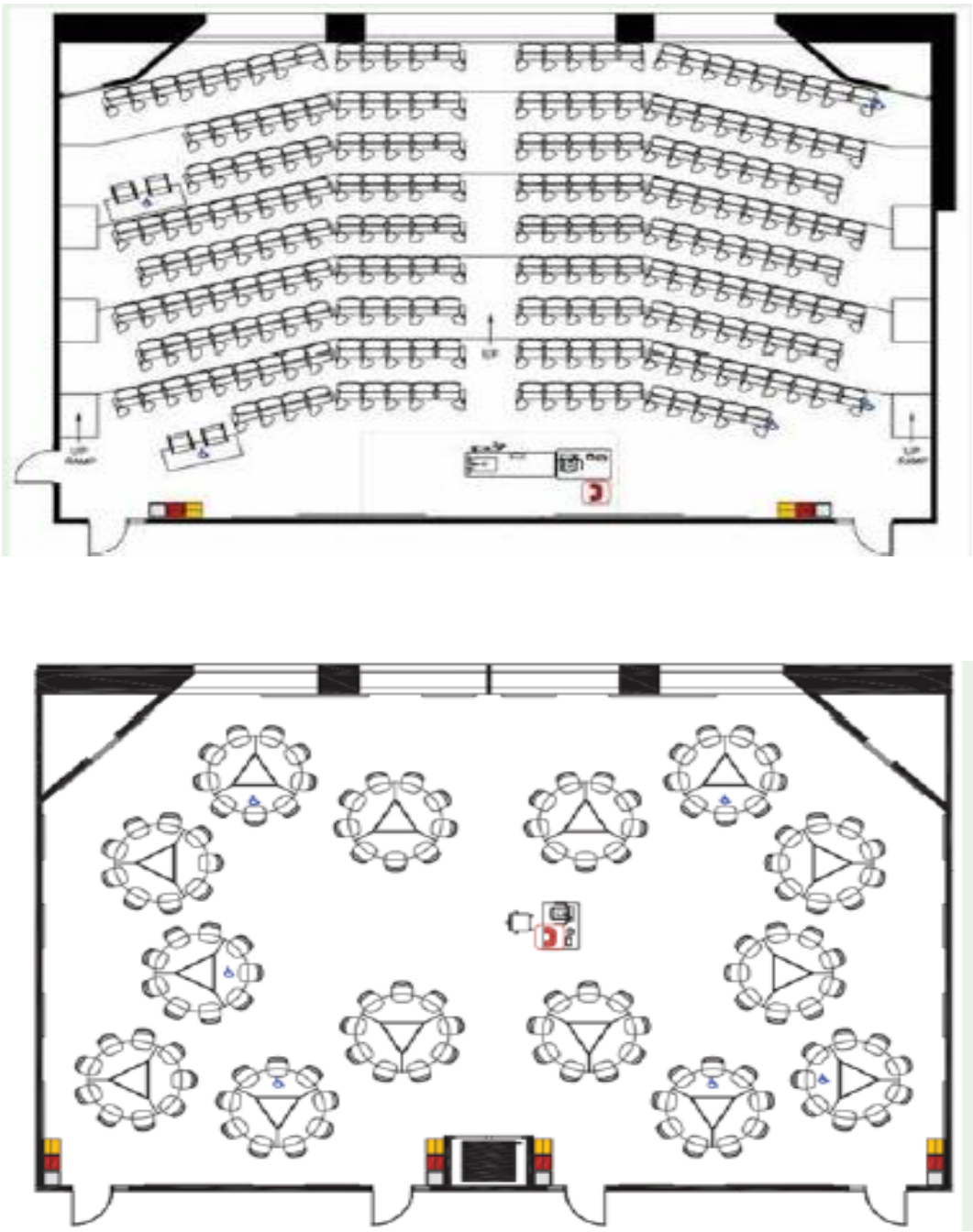

Figure 2-1. Layout of a traditional classroom (top) in which the seats are arranged in rows and forwards facing vs. a technology-infused classroom (bottom) in which the seats are arranged in pods and distributed across room (This figure is adopted from *Journal of College Science Teaching*, 42, pp 83, (2013)).

2013). Software designers argue that they provide students with self-regulation and mastery of the subject matter (Warnakulasooriya et al., 2005; Amaral et al., 2013; Libman & Huang, 2013). These web applications are becoming popular, especially in large introductory level classes, both as a learning tool and as an assessment tool. Recent research efforts in science education in collaboration with cognitive, physical, and life sciences revealed how students perceive and interpret various kinds of multimedia presentations and molecular animations (Charlesworth & Vician, 2003; Wu & Shah, 2004; Barak & Dori, 2005; Jones, 2013; Amaral et al., 2013; Libman & Huang, 2013). They generally conclude that, these technological tools will potentially attract students to obtain interactive and effective learning experiences in STEM fields (Jones, 2013; Libman & Huang, 2013).

The primary goal of the previously discussed instructional innovations is to promote learners' knowledge construction. Thus all of these technological and learning space innovations are rooted in learner-centered pedagogy. Therefore, constructivist learning theory was chosen as the theoretical framework for this study.

2.2 Constructivist learning theory as the theoretical framework

Constructivism as a framework for learning identifies that knowledge is constructed by the learners' as they attempt to make sense of the world (Bodner, 1986; Driver, & Oldham, 1986; Tobin, 1993; Fensham, et al., 1994; Staver, 1998; Windschitl, 2002; Richardson, 2003; Driscoll, 2005; Fosnot, 2005). Stated in different words, individuals create their own new understandings of the world on the basis of an interaction between what they already know (prior knowledge) and believe, and ideas and knowledge (new knowledge) with which they come into contact (Richardson, 2003).

According to the constructivist view, learners are considered to be actively engaged in learning *via* inquiring, seeking meaning of their experiences and the world around them. (Bodner, 1986; Driver, & Oldham, 1986; Tobin, 1993; Fensham et al., 1994; Windschitl, 2002; Driscoll, 2005). Explaining further, knowledge is actively built

up from within by a thinking person; it is not passively received; social interaction between and among learners is central to building the knowledge (Staver, 1998). According to the constructivist view, the constructive process helps learners to expand their mental structures by adding new knowledge. When conflicts arise, new mental structures are formed to make sense of the new material. This constructed knowledge must be viable; *i.e.* it should be constructed as the best construction of human experience of the world. This view is in contrast to behaviorism and information processing, which has roots in objectivism (Bodner, 1986; Driver, & Oldham, 1986; Staver, 1998; Richardson, 2003; Driscoll, 2005).

Ideas about constructivism go back several decades, yet constructivist pedagogy as a practice is fairly new (Windschitl, 2002; Richardson, 2003). This is due to the difficulty of translating the constructivist ideas into practice (Matthews, 2003; Richardson, 2003). Some researchers suggest that constructivism is not a theory itself but a 'model of knowing' which may be built into a theory of learning (Richardson, 2003). Constructivist learning theory has components that aligns with Piaget's cognitive development and Vygotsky's social constructivism (Fensham et al., 1994; Windschitl, 2002; Driscoll, 2005; Fosnot, 2005) Some researchers also argue that Dewey's developmentalism approaches such as discovery learning and authentic learning were transformed into constructivist teaching practices (Windschitl, 2002; Matthews, 2003). Many researchers have worked to reform the educational practices in accordance with constructivist teaching principles (Driver, & Oldham, 1986; Tobin, 1993; Fensham, et al., 1994; Staver, 1998; Windschitl, 2002; Richardson, 2003; Driscoll, 2005; Fosnot, 2005).

Constructivist learning goals are designed to focus on higher order thinking skills such as reasoning, critical and creative thinking, which helps learners to develop deep understanding of the subject matter and habits of mind that aids future learning (Driscoll, 2005; Richardson, 2003; Windschitl, 2002). These learning goals focus on learners' abilities to understand the use of knowledge, and their abilities to identify and pursue

their own learning goals, which can be termed as self-regulation, self-awareness and mindful reflection (Driscoll, 2005; Richardson, 2003; Windschitl, 2002).

According to the constructivist view, conditions for learning need to accommodate the above learning goals (Driver, & Oldham, 1986; Staver, 1998; Windschitl, 2002; Richardson, 2003; Driscoll, 2005). One such condition is that students must be provided with the opportunities to engage in complex, meaningful, problem-based activities embedded in relevant realistic environments. Another condition is that students must be encouraged to work collaboratively, thereby providing support to engage in task-oriented dialogue with one another. Getting students to question, clarify, defend, elaborate, evaluate and argue with each other is an integrated part of constructivist based learning. Encouragement of ownership of learning and nurturing self-awareness is another important condition. Other important conditions to support learning include providing students with a variety of information resources and tools necessary to mediate learning, and allowing students to apply knowledge in diverse and authentic contexts to explain ideas and construct arguments based on evidence. Finally, teachers need to employ a variety of assessment strategies to understand how students' ideas are evolving and to give feedback on the processes of their thinking (Driver, & Oldham, 1986; Staver, 1998; Windschitl, 2002; Richardson, 2003; Driscoll, 2005).

Since the constructivist learning theory's main focus is active knowledge construction by the learners themselves, constructivist methods of instruction primarily follow a learner-centered approach. These instructional methods involve problem-based learning, collaborative and/or cooperative learning (group learning), debates, projects-based learning, multimedia infused learning, and guided inquiry learning. These methods of instruction support learners' own construction of knowledge *via* creating realistic situations and social settings that align with learning goals and conditions described above (Driscoll, 2005; Fensham et al., 1994; Tobin, 1993; Windschitl, 2002).

When examined closely, it is evident how instructional technological tools and innovative learning spaces designs are guided by constructivist learning goals, learning conditions, and methods of instruction. For example, innovative learning spaces designs facilitate constructivist methods of instruction such as collaborative and/or cooperative learning, projects-based learning, and inquiry-guided learning etc. (Beichner, 2006; Gaffney et al., 2008; Brooks, 2011; Van Horne et al., 2012; Cotner et al., 2013; Florman, 2014). Further, innovations in technological tools provide multimedia infused learning capabilities for students so that they are able to access the resources easily, visualize the subject matter effectively, and pursue their own learning goals in a self-regulated manner (Amaral et al., 2013; Charlesworth & Vician, 2003; Dori & Belcher, 2005; Dancy, 2006; Dori et al., 2007; Ellis, 2013; Enriquez, 2010; Jones, 2013; Libman & Huang, 2013; Muthyala & Wei, 2012; Warnakulasooriya et al., 2005). Moreover, trends in novel technology and learning space designs provide students with a variety of resources and tools to mediate their learning and apply their knowledge in diverse and authentic contexts, work collaboratively with their peers, and use higher-order thinking skills to clarify, defend, and elaborate their understanding (Beichner, 2006; Brooks, 2011; Van Horne et al., 2012; Cotner et al., 2013; Muthyala & Wei, 2012; Warnakulasooriya et al., 2005; Dancy, 2006; Dori et al., 2007). Likewise, instructional technological tools and novel learning space designs also enable instructors to employ a variety of on-going informative assessment strategies to evaluate their students' learning processes (Dancy, 2006; Dori et al., 2007; Ellis, 2013; Enriquez, 2010; Jones, 2013; Libman & Huang, 2013; Muthyala & Wei, 2012; Warnakulasooriya et al., 2005).

2.3 Innovative instructional strategies and college professors

A considerable number of research studies have investigated how K-12 school teachers (both pre-service and in-service) perceive technology use in their classrooms, and how they incorporate inquiry guided, team-based, active learning instructional strategies in their classrooms. (Niess, 2005; Koehler et al., 2007; Koehler & Mishra,

2009; Harris et al., 2009; Schmidt et al., 2009; Jang & Chen, 2010; Kramaski & Michalsky, 2010; Khan, 2011; Hofer & Grandgenett, 2012). These research studies found evidence for the existence of a technological knowledge base and ways to measure the development and impact of technology on both teacher effectiveness and student learning. However, as several authors pointed out (McKeachie, 1990; Rutherford & Grana, 1995; Felder & Brent, 1996; Grasha & Yangarber-Hick, 2000), similar studies regarding college professors' perceptions of technology use are limited in the higher education literature. This gap in the literature needs to be filled as it relates to many aspects of current interests in undergraduate education. First of all, graduate students (particularly in STEM disciplines) usually do not gain pedagogical training prior to becoming college professors (as opposed to K-12 teachers), thereby lacking a rich pedagogical knowledge base (Spencer, 1999).

Progression towards learner-centered cultures to accommodate recent technological and pedagogical advancements implies that college professors have to be creative and productive in conducting their classes (McKeachie, 1990; Rutherford & Grana, 1995; Felder & Brent, 1996; Grasha & Yangarber-Hick, 2000; Miller et al., 2000; Brown et al., 2004). In order for college professors to meet these demands, they need to be introduced to the pedagogical reasoning of incorporating technology in their classrooms to promote successful active learning opportunities for their students. College professors who lack a rich pedagogical knowledge base for teaching sciences can easily face challenges in terms of accommodating appropriate technologies and instructional practices when placed in a technology-infused active learning environment. Existing research studies document that college professors need to be informed regarding the teaching and learning opportunities they can create in terms of conducting their classes in technology-infused interactive learning spaces (Brown et al., 2004). Thus, a successful support model should include not only methods for helping instructors use technology, but a system for helping the instructor plan learning activities that take advantage of the

available technological tools and instructional resources (Van Horne et al., 2012). Even though the college professors are successful in adopting novel instructional strategies in their classrooms, embracing a learner-centered teaching culture cannot occur in isolation. Movement towards a learner-centered paradigm and related teaching and learning cultures needs to be part of an agenda that involves the administration, entire departments and the institution as a whole (Schnieder & Shoenberg, 1999; Bok, 2009). Higher education institutions need to evaluate the purposes of their undergraduate curricula, related instructional strategies, assessment strategies, as well as faculty scholarship of teaching and learning in order to successfully implement and disseminate innovative instructional decisions and practices (Schnieder & Shoenberg, 1999; Hubba & Freed, 2000; Paulsen & Feldman, 2002; Bok, 2009).

CHAPTER 3

METHODS

Chapter 3 discusses the research methods employed in this study. Sections 3.1 and 3.2 include detailed descriptions of research design and research context respectively. Sections 3.3, 3.4 and 3.5 comprise detailed descriptions about research participants, data collection methods, and data analysis methods.

3.1. Research design

This study is a multiple-case study of four college professors who conducted their undergraduate science classes in a technology-infused interactive learning space based on the 'SCALE-UP' model in a large public Midwestern university.

Case study research is defined as a qualitative tradition that explores a certain issue or a situation through one or more cases within a bounded system (setting or a context). Case study research tries to answer in-depth descriptive research questions; particularly questions about developing an in-depth understanding about how different cases provide insight into an issue or a unique situation. When several units of analysis such as several individuals are chosen to illustrate a given situation of interest, it is known as a collective or a multiple case study (Creswell, 1998; Creswell et al., 2007; Merriam, 2009).

A multiple case study design is particularly suitable for this study in that it explores college professors' perception of technology use and the extent to which their instructional decisions and practices are affected by teaching in interactive learning spaces. Therefore, the differences in disciplinary backgrounds, teaching experiences, and exposure to novel teaching strategies found in these four participating college professors can provide an in-depth understanding into how technology-infused interactive learning spaces are collectively perceived by faculty members. Ultimately, the insight gained through this multiple-case study can better inform the development of effective professional development workshops and support programs for college professors.

3.2. Research context

The context of this study was a technology-infused interactive learning space known as a TILE (Transform-Interact-Learn-Engage) classroom. Learning spaces such as TILE classrooms were developed following the SCALE-UP classroom model developed at North Carolina State University (Beichner, 2006; Florman, 2014; Ingram et al., 2013; Van Horne et al., 2012; Van Horne et al., 2014) to accommodate student-centered teaching strategies and to promote student engagement in undergraduate courses.

3.2.1. Technology-infused interactive learning space (TILE classroom)

Key components of the TILE classrooms include circular tables, student laptops, flat screen monitors, multiple projectors, and glass-whiteboards. These features can be used to promote student-centered activities and encourage collaborative learning through student discourse. The instructor workstation/podium is in the middle of the room, as opposed to the front as is typical in a traditional lecture-based classroom. This arrangement increases the mobility and accessibility of the instructor, promoting student-instructor discourse (Florman, 2014; Ingram et al., 2013; Van Horne et al., 2012). Figures 3-1 and 3-2 provide the layout and arrangement of the TILE room.

The TILE classroom chosen for this study is equipped with nine fixed round tables with nine movable chairs per each table, enabling the accommodation of 81 students at a time. Each round table has a built-in microphone and has three laptops with internet connection. Each table has an assigned glass whiteboard space and an LED (light emitting diode) screen mounted on the walls. There are four projectors in the room. These are capable of projecting lectures slides and course materials around the room so that every student gets a clear view of them. The instructor workstation is equipped with a smart podium, a Blu-ray player, a microphone drawer, and a document camera. By

Figure 3-1. Arrangement of the TILE classroom utilized in this study.
Source:http://libjournal.uncg.edu/index.php/jls/article/viewFile/344/280/1709

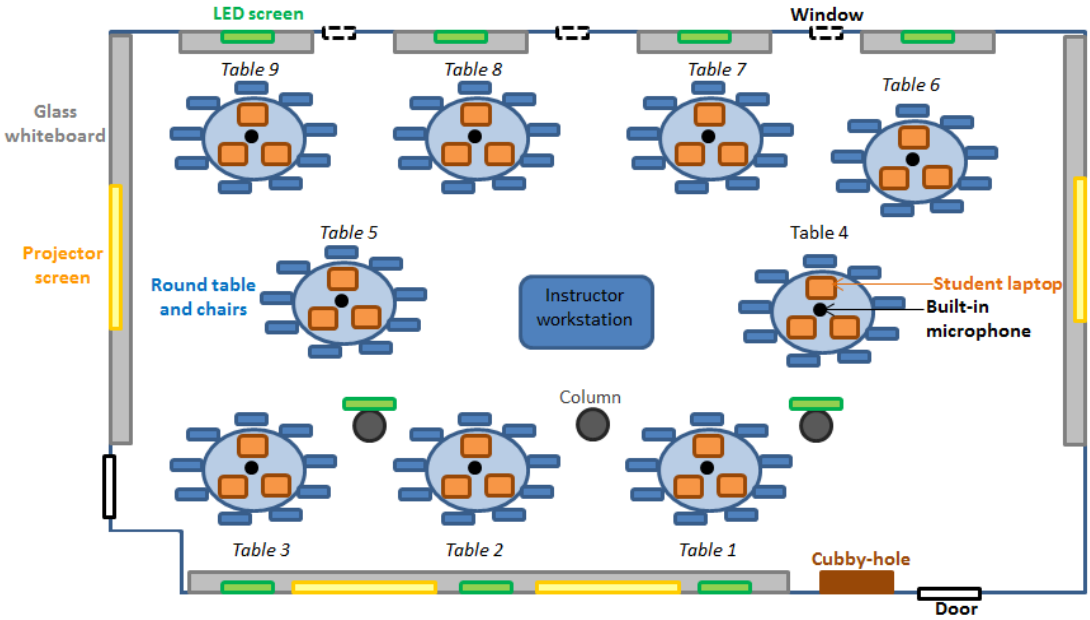

Figure 3-2. Bird's eye view of the layout of the TILE classroom utilized in this study.

utilizing the information technology (IT) resources in this room, the instructor can project material from the central podium to many screens around and can also showcase student work by projecting individual laptop screens around the room. Each LED screen, in particular, can project specific content at a given time, whereas the four projectors are capable of projecting the same content across the room (Florman, 2014; Ingram et al., 2013; Van Horne et al., 2012). Table 3-1 documents the available learning space features and IT resources of this TILE room along with their intended outcomes.

3.3. Study participants

This study investigated the instructional decisions and practices of four college professors as they taught their class sessions in the TILE classroom over the course of one semester. Participants have expertise in natural and social science disciplines and represent four different departments in the university. Background information of the four participants is provided in table 3-2.

At the time of the study, Dr. Smith, Dr. Davis, and Dr. Johnson were teaching introductory science courses that were intended to fulfill the general education requirement in natural sciences for non-science majoring students. Of the above three participants, Dr. Davis and Dr. Johnson were members of an interdisciplinary constellation course taught across multiple departments. Dr. Baker was teaching an advanced science course intended for student majors and minors of her discipline. Information regarding course demographics and enrollments are summarized in Table 3-3.

3.3.1. Participant selection criteria

Participants of this study were purposefully selected using the following criteria. Firstly, all potential participating college professors needed to have completed the TILE training program conducted by the university to become eligible to teach in a TILE classroom prior to the semester of data collection. This criterion provided a total population of 89 faculty members as potential participants (http://tile.uiowa.edu).

Table 3-1. Available learning space features and IT resources in the TILE classroom and their intended learning outcomes.

Available learning space features and IT resources	**Intended outcome**
• Smart podium • Microphone for instructor • LED screens • Multiple projectors • Document camera • Blu-ray player	• Present course materials (lecture slides, class worksheets, videos, simulations, animations etc.) to the class • Provide administrative information such as course announcements • Administer class activities, worksheets, student response system questions (such as clickers) etc. to the class Conduct summary discussion and closing remarks
• Round tables • Glass whiteboards • Student laptops	• Promote small group discussions and activities Promote hands-on learning with web-based tools, models, specimens etc.
• Round tables • Glass whiteboards • Student laptops • Student microphones • Microphone for instructor • Smart podium • Document camera • LED screens • Multiple projectors	• Promote large group discussions and activities • Report out answers/findings to the class Promote whole class discussions

Table 3-2. Background information of study participants.

Participant Pseudonym	Gender	Years of teaching experience	Experience in teaching in a TILE classroom	Discipline of expertise
Dr. Smith	Male	4	4 semesters	Biology
Dr. Baker	Female	4	1 semester	Chemistry
Dr. Davis	Female	12	3 semester	Physics & Astronomy
Dr. Johnson	Male	16	1 semester	Anthropology

Table 3-3. Course demographics and enrollment.

Participant	Course enrollment	Course information and scope	Course specifications
Dr. Smith	72 (Primarily freshman and sophomore students)	Introductory biology course focusing on evolution and natural selection	Meets the general education requirement (without a lab) in natural sciences for non-science majors
Dr. Baker	78 (Junior and senior students)	Advanced chemistry course focusing on inorganic chemistry principles and applications	Required for chemistry majors Elective for chemistry minors
Dr. Davis and Dr. Johnson	50 (Primarily freshman and sophomore students)	Introductory interdisciplinary sciences course focusing on "Big Questions" such as the origin of the Universe, solar system and Earth, origin of life on Earth, origin of humans etc. (Conducted as a constellation course in-combination with multiple departments)	Meets the general education requirement (with a lab) in natural sciences for non-science majors

Next, the study context was restricted to one of the two largest TILE classrooms in the university with the expectations of (1) including large introductory (undergraduate) science courses in this study and (2) keeping the learning space and available technologies the same throughout the course of the study. This second criterion reduced the above population of potential participants to about 10 faculty members. Out of these potential participants, four college professors expressed their interest and volunteered to participate in this study.

3.3.2. Participants' backgrounds and course demographics

3.3.2.1. Dr. Smith

Dr. Smith is an assistant professor of biology with four years of teaching experience in the university. He learned about the TILE classrooms from colleagues in his department. He had been teaching in TILE classrooms for four semesters.

The course he was teaching the semester of the study was an introductory biology course that meets the general education requirement in natural sciences (without a lab) for non-science majoring students. This course discusses the nature of science, process of evolution, and underlying processes affecting biological change; examines the lines of evidence used to reveal evolutionary patterns; and investigates patterns of organismal diversity that have resulted from evolutionary change. This course had 72 students enrolled in it, the vast majority of whom were freshman and sophomore students.

Dr. Smith had taught this particular course three times before and every time in the TILE classroom setting. However, he had taught other introductory biology courses in traditional lecture-room settings.

3.3.2.2. Dr. Baker

Dr. Baker is an assistant professor of chemistry with four years of teaching experience in the university. She learned about the TILE classrooms from a colleague in another department. This was her first semester teaching in a TILE setting.

The course she was teaching the semester of the study was an advanced chemistry course focusing on inorganic chemistry principles and applications designed for junior and senior students. This course is required for students who are majoring in chemistry and is an option for students who are chemistry minors. Topics covered included descriptive chemistry of selected main group and transition elements, molecular structure, symmetry, and inorganic stereochemistry. These concepts are connected to real world examples in environmental chemistry, including transport of inorganic contaminants and nanomaterials in natural systems. This course had 78 students enrolled in it. The majority of the students (~ 60%) were chemistry minors and the rest were chemistry majors.

Dr. Baker had taught this particular course in a traditional lecture-room setting for three semesters before but this was her first time teaching it in a TILE classroom setting.

3.3.2.3. Dr. Davis

Dr. Davis is an associate professor of physics & astronomy with twelve years of teaching experience in the university. She learned about the TILE classrooms from colleagues in other departments and from the university's Center for Teaching in the university. She had three semesters of teaching experience in TILE classrooms.

The course she was teaching during the semester under study was a year-long, interdisciplinary course implemented as a constellation course across multiple departments. This study only included the second semester of this course. It is an introductory course that meets the general education requirement in natural sciences (with a lab) for non-science majoring students. This course is designed to formulate answers to "Big Questions" such as 'How old is the Universe?' 'What is the nature of life?' 'How has life evolved on Earth?' 'What are our human origins?' 'Are there other habitable planets in the Universe?' etc. These fundamental questions were addressed from different perspectives such as astronomy & physics, geoscience, biology, chemistry,

and anthropology. This course had 50 students enrolled in it. The vast majority were freshman and sophomore students.

Dr. Davis had never taught this particular course before, but she had taught similar material in another course both in traditional lecture-room and TILE classroom settings for several semesters.

3.3.2.4. Dr. Johnson

Dr. Johnson is a professor of anthropology with sixteen years of teaching experience in the university. He learned about the TILE classrooms from colleagues in other departments. He was teaching a course in the TILE classroom for the first time in the semester of the study.

Dr. Johnson was co-teaching the same course as Dr. Davis, thus the course demographics and enrollment were the same. Dr. Johnson had never taught this particular course before, but he had taught similar material in another course in traditional lecture-room settings for several years.

3.4. Data collection methods

In general, case study research utilizes multiple sources of data such as participant observations, interviews, documents, audio-visual materials, and physical artifacts to gather detailed information regarding the case(s). Use of multiple data sources allows researchers to triangulate research findings across different data sources and to further develop an in-depth and rich understanding of the issue or the unique situation of interest (Creswell, 1998; Creswell et al., 2007; Merriam, 2009).

This study employed three data collection methods: questionnaires, classroom observations, and semi-structured interviews. A questionnaire was administered at the beginning of the study to gather demographic data regarding the participants' backgrounds. The information collected through this questionnaire contributed to enriching the detailed descriptions generated regarding each case/participant (Merriam, 2009). The questionnaire consisted of questions regarding participants' overall teaching

Table 3-4. Summary of data sources collected in this study

Data Source	Purpose	Data Collection Points
Questionnaire	To gather background information regarding participants' teaching experiences and course details	Beginning of the study
Classroom observations	To document participants' instructional practices, aspects of technology and learning space use during each observed class session	During the semester (three class sessions per participant)*
Semi-structured interview	To gather in-depth information regarding participants' overall perception of interactive learning spaces and instructional technology use in undergraduate classrooms	End of the semester

*except in the case of Dr. Johnson who only had two classroom observations.

experiences, teaching experiences in TILE classroom settings, discipline of expertise, and course they are teaching etc. Table 3-4 summarizes data sources collected for this study.

Non-participant observations are a widely used data collection method in qualitative research designs. Observations allow researchers to record a behavior as it is happening. Further, observations are the best way to gather firsthand information regarding specific behaviors of participants that inform the research purpose and subsequently to follow up with in-depth interviews (Bogdan& Biklen, 2003; Merriam, 2009; Spradley, 1980). Classroom observations of all four participants were a critical data source in this study. This is mainly due to the fact that participants' use of the instructional technologies and learning space features in a TILE classroom provided useful insights into their familiarity with and overall perception of innovative instructional strategies and technologies.

Interviews are widely used in qualitative research in which the researcher and the participant engage in an informing conversation related to the research study. When using a semi-structured interview, interview questions are often reframed or created in response to an interviewee's replies in order to gain a better understanding of an issue under study. Thus, interview questions are usually administered in a flexible manner and designed to address specific research questions required by the study (Fontana & Frey, 1994; Merriam, 2009; Patton, 1990). Semi-structured interviews were especially useful for this study because they provided detailed information regarding participants' pedagogical reasoning and decision making processes, particularly with respect to the classroom observations that were carried out prior to the interviews. Moreover, these semi-structured interviews provided critical and comprehensive information concerning participants' perceptions of innovative instructional strategies and technologies thus informing the main purpose of this study.

3.4.1. Questionnaire

Each participating faculty member was asked to complete a questionnaire at the beginning of the study to gather information regarding their teaching experiences and course details. This questionnaire included a total of eight questions representing two main categories: participant's teaching experience (years of teaching as a faculty member, teaching experiences in TILE rooms, frequently used IT resources, and TILE room features etc.,) and course demographics (course requirements, enrollment, course composition etc.). Completion of the questionnaire took about 15- 20 minutes. A copy of the questionnaire can be found in appendix A.

3.4.2. Classroom observations

Each participating faculty member except Dr. Johnson was observed three times during their class sessions in the TILE classroom to document their instructional strategies, classroom activities, types of instructional technologies used, etc. These classroom observations were digitally recorded using a JVC Everion 3CCD hard disk camcorder. The three class sessions to be observed for each participant were randomly selected to capture the general flow (natural and authentic classroom behavior of instructor and students) of the course over the semester. Only two classroom observations were conducted with Dr. Johnson due to scheduling conflicts. All classroom observations were translated verbatim for data analysis. The classroom observation protocol can be found in appendix B.

3.4.3. Semi-structured interviews

All four participating faculty members were individually interviewed once at the end of the semester utilizing a semi-structured interview protocol. The purpose of the interviews was to gather detailed and in-depth information regarding the types of instructional strategies they employed, the degree of instructional technology used, the types of learning space features used, and their overall perception of instructional technology and interactive learning spaces used in undergraduate courses. These interviews were digitally recorded using an OLYMPUS LS-10 linear PSM recorder. The

interview protocol can be found in appendix C. All interviews were translated verbatim for data analysis.

3.5. Data analysis methods

Data collected from the multiple sources were analyzed using two main data analysis methods: an enumerative approach and the constant comparative method. Detailed descriptions of these two methods are presented in sections 3.5.1 and 3.5.2.

3.5.1. Enumerative approach

An enumerative approach was used for the analysis of classroom observations. This method provides a numbers-oriented view (Grbich, 2007) such as a total count, a fraction, a percentage occurrence of certain events or actions that occurred during a given period of observation. For example, I used the enumerative approach to document: (1) the types of classroom activities each participant used, (2) the types of instructional technologies each participant employed, (3) the types of learning space features each participant utilized, and (4) the percentage time allocations for each classroom activity. Therefore the main purpose of the enumerative approach was to develop a profile that depicts each college professor's choice of (1) classroom activities, (2) instructional technologies, and (3) interactive learning space features. Such profiles were generated for each participant to address the general overview of their instructional practices as well as their specific instructional decisions for each given observation day. In this study, the enumerative approach was primarily used to formulate answers to research question 1:

> What aspects of the learning environment and available technologies in technology-infused interactive learning spaces do college professors utilize and what are their pedagogical reasoning behind them?

3.5.2. Constant comparative method

A constant comparative method was used as the main method of data analysis for transcripts generated from interviews and classroom observations. This is an inductive analysis method that aids the generation of explicit categories and subcategories based on

the identification of similarities or common patterns found in the data (Boeije, 2002; Glaser & Strauss, 1967; Kolb, 2012; Strauss & Corbin, 1990). In this study, the constant comparative method was primarily used to formulate answers to research questions regarding 1) college professors' pedagogical reasoning, 2) influences of instructional technology and learning space features, and 3) overall perceptions of instructional technology and learning space features.

The first step was the generation of transcripts from classroom observations and semi-structured interviews using the 'Inscribe' transcription software. This step yielded 11 total transcripts for classroom observations and 4 total transcripts for semi-structured interviews.

These transcripts were then coded using a computer-assisted qualitative data analysis software termed 'Atlas ti'. Coding is a common approach in qualitative research during which a shorthand notation (single words, small phrases of words, letters and /or number combinations etc.) is used to identify and easily retrieve specific portions of data (Merriam, 2009). An open coding approach was used during this study. Open coding does not employ a pre-established system of categories or codes: instead it uses the aspects and foci of the texts themselves to identify and describe a certain occurrence or a phenomenon found in the transcripts. This data analysis process is inherently inductive in the sense that explanations or the meaning making is essentially derived from the data themselves (Boeije, 2002; Glaser & Strauss, 1967; Kolb, 2012; Merriam, 2009; Miles & Huberman, 1994; Saldaña, 2013; Strauss & Corbin, 1990). Use of open coding in this case was particularly beneficial because it enabled the focus on the 'statements' and 'actions' of college professors' rather than being biased or limited by pre-existing codes. All the transcripts were independently coded to generate a collection of codes. This process was repeated three separate times to increase the reliability of coding by minimizing bias at each individual coding step. Once the analysis was completed and the redundancies were accounted for, there were 134 total codes in the code list.

Subsequently, categories and subcategories were generated based on the similarities found by comparing the codes across participants and across data sources. Categories and subcategories are identified as grouped patterns and recurring regularities in the data. Construction of subcategories and categories includes clustering common patterns and regularities in data that are responsive to the research purpose and research questions. A given subcategory explicitly explains a distinct feature in the data. A given category encompasses similar subcategories thus generating a common theme concerning a specific research question (Merriam, 2009; Miles & Huberman, 1994; Saldaña, 2013). In this approach, focus was placed on the identification of common patterns that emerged from the data in terms of college professors' instructional practices and decision making, and their overall perception of instructional technology and interactive learning spaces. Furthermore, each research question was addressed separately to formulate mutually independent, non-redundant categories.

During this step, I regularly met with an independent researcher to discuss code descriptions, my interpretation of categories and subcategories, and the process of category generation. This peer-debriefing step helped in reaching a consensus regarding the number of categories, subcategories, and their interpretations. Table 3-5 provides examples of themes/categories, subcategories, and codes generated during the data analysis process. A complete list of codes generated, along with their descriptions, and a list of categories and subcategories generated, along with their descriptions, can be found in appendix D.

Furthermore, another independent researcher coded 25% of the data transcripts (representing transcripts from all four participants) and independently developed categories and subcategories to address RQ2 and RQ3 (these categories and subcategories can be found in appendix D). Inter-rater reliability for the categories and

Table 3-5. Examples of category generation and related codes from the data analysis process.

RQ	Related categories and subcategories	Codes involved
RQ1: Pedagogical reasoning	*(1)Increase student engagement:*	
	• Encourage student-student interaction	Student engagement Students talk to each other
	• Encourage student-instructor interaction	Students ask questions Students talk with instructor/TA
	• Use new technologies available	Doc-cam Student laptops Videos Web simulations Whiteboards Wikisite
RQ2: Influence of instructional technology and learning space features	*(1)Lesson planning stage:*	
	• Extensive planning	Big ideas Co-teaching member input Learning goals/objectives
	• Reflection on previous experiences	Own reflections Previous course experiences Previous TILE experiences
RQ3 Overall perception of instructional technology and learning space features	*(1)Benefits:*	
	• Increased student discourse	Active learning for students Student discussion/dialogue Student-instructor dialogue Student-TA dialogue Team-based learning
	• Ability to be flexible and creative when conducting classes	Confidence Fun experience/great experiences Not lecturing in class
	(2) Challenges:	
	• Difficulty in designing effective classroom activities	Breadth/depth in activity writing Time consumption Trial and error
	• Lack of recognition and appreciation for what they do	Pushback from colleagues/ department Teaching vs research balance Team-teaching issues Tenure/promotion issues

subcategories development was calculated to be 90%. This independent category/subcategory development step further ensured the reliability of the data analysis process.

3.6. Positioning/subjectivity statement

When I think about positioning of my own subjectivities in the context of this study, I would declare the following. Being a science educator, my teaching philosophy centers around creating an engaging environment that motivates students to participate in informative discussions of science concepts and applications. Therefore I think that students need to actively participate in class and we as science educators need to provide the opportunities for them to do that by creating an interactive learning environment. Thus my own belief in active student participation in the classroom is a lens that I acknowledge I have.

3.7. Ethical considerations

One ethical consideration I had throughout this study was how my study participants perceived my role as the researcher. For example, what if my participants felt that I was judging his/her content knowledge proficiency or the quality of teaching during classroom observations and interviews. I had no intentions of judging his/her content knowledge or how accomplished he/she was as a college professor for this project. But I always felt that it can be a complicated balance when you conduct classroom observations and interviews with college professors for research projects. Even though how unintended it may seem, participants may feel uncomfortable and may take the classroom observations and interviews to be personal evaluations or judgments of their teaching.

CHAPTER 4

RESULTS AND MAIN FINDINGS

Chapter 4 includes the results and main findings of this study. These results and findings are presented according to their respective research question (RQ). Sections 4.1, 4.2, and 4.3 discuss the findings related to RQ1, RQ2, and RQ3 respectively. The three research questions that guided this study are reiterated below.

RQ1: What aspects of the learning environment and available technologies in technology-infused interactive learning spaces do college professors use and what are their pedagogical reasonings behind them?

RQ2: How do technology-infused interactive learning environments influence college professors' instructional decisions and practices at following stages: lesson planning, lesson execution, and student assessment?

RQ3: What are college professors' perceptions of technology-infused interactive learning environments in terms of benefits, difficulties, and desired support?

4.1 Results and findings concerning research question 1

Research question 1 (RQ1) intended to investigate college professors' use of available instructional technologies and learning space features in the TILE classroom setting. RQ1 further investigated how college professors make decisions about which instructional technologies and learning space features to use, when to use them, and why. A participant profile for each college professor was created in order to address the findings of RQ1 in detail. These include a basic overview of how each participant managed their course, specific types of instructional technologies, learning space features, and classroom activities they used regularly, as well as in a given observation day.

4.1.1 Participant profiles

Many similarities and differences were found across the four participants' cases with respect to their choices to use different types of instructional technology and

learning space features in their classrooms. These similarities and difference are summarized in Tables 4-1 and 4-2.

As shown in Table 4-1, all the participants managed their courses online, *via* a course websites centrally administered by the university information technology services. All the class materials such as course syllabi, announcements, class handouts/slides, and grades were administered through these websites. Furthermore, all four college professors employed inquiry-guided activities to address the topics of each class session. In all four courses, students were organized into assigned groups (formed in the beginning of the semester) usually consisting of three members. All four courses used a team-based learning approach employing the round table structure in the TILE classroom. Each college professor also used the central podium/workstation, projector screens, and LED screens regularly to present class materials (usually in the format of PowerPoint slides) along with the wireless microphones. All four college professors had a specifically written policy (in their syllabi) that did not permit the personal use of cell phones, tablets, and laptops during class. They all brought models, specimens, casts, demonstration materials, and/or other learning tools (to be used in classroom activities) to class on multiple occasions. All of them took advantage of the round table arrangement to enable hands-on activities for their students. Dr. Smith, Dr. Davis, and Dr. Johnson regularly used whole class discussions in their class sessions, while Dr. Baker didn't conduct whole class discussions.

However, none of the participants using whole class discussion used the built-in student microphones regularly. During observations of whole class discussions, they either used one or two handheld-wireless microphones, occasionally using the built-in microphones as a supplement, or did not use any microphones at all. During the interviews, some participants expressed their concern regarding the quality of the built-in

Table 4-1. Summary of the types of digital and non-digital instructional technologies the four college professors used in their classrooms. 'Y' indicates the types of instructional technologies used on a regularly basis, 'N' indicates the types not used at all and 'Y(NR)' indicates the types not used regularly.

Type of instructional technology	Participant's choice of use		
	Dr. Smith	**Dr. Baker**	**Dr. Davis and Dr. Johnson**
(1) Digital technology			
Course website	Y	Y	Y
Wiki site	Y	N	N
Blog	Y	N	N
Lecture capture software	N	Y	N
Specialized software (Mathematica etc.)	N	Y	N
Power point slide presentations	Y	Y	Y
Online in-class activity templates	Y	Y	N
Web based tools and simulations	Y(NR)	Y(NR)	Y(NR)
YouTube and other instructional videos	Y(NR)	Y(NR)	Y(NR)
Other World wide web resources	Y(NR)	Y(NR)	Y(NR)
Student Response System – Clickers	N	Y	N
(2) Non-digital technology			
Paper-based in-class activity templates and folders	Y(NR)	N	Y
IF-AT quiz forms	N	N	Y
Model kits, casts, specimens, and other teaching/learning demonstrations	Y(NR)	Y(NR)	Y(NR)

Table 4-2. Summary of the types of TILE learning space features the four college professors used in their classrooms. 'Y' indicates the types of instructional technologies used on a regularly basis, 'N' indicates the types not used at all and 'Y(NR)' indicates the types not used regularly.

Type of TILE classroom learning space feature	Participant's choice of use		
	Dr. Smith	Dr. Baker	Dr. Davis and Dr. Johnson
Smart podium/ work station	Y	Y	Y
LED monitors and projector screens (to present materials)	Y	Y	Y
LED monitors and multiple projector (to report out)	Y(NR)	N	Y(NR)
Blu-ray player	N	N	N
Microphone for instructor	Y	Y	Y
Document camera (doc-cam)	Y	N	Y
Round tables	Y	Y	Y
Student laptops	Y	Y	Y(NR)
Built-in microphones on round tables	Y(NR)	N	Y(NR)
Glass whiteboards	Y	N	Y

microphones such as the static noises generated by them. Furthermore, they expressed a desire to explore innovative ways to improve student communication across the tables in the TILE room.

Although there were many similarities, the four college professors also had some differences concerning how they structured and conducted their courses. For example, Dr. Smith and Dr. Baker managed all of their inquiry-guided activities online. Therefore, the students in these two courses used the laptops provided on the round tables to access and work on the activities/worksheets regularly. Once the students had completed the activities, they were submitted to a dropbox set up through the course website for evaluation purposes. In the cases of Dr. Davis and Dr. Johnson, even though the activities/worksheets were paper-based, they still had an explicit filing system to manage the paper-based activities for each group.

As shown in table 4-2, all the participants except for Dr. Baker used the glass whiteboards to have students report out their answers and findings of the group discussions. Similarly, all the participants except for Dr. Baker also used the LED screens to showcase/share student work (mentioned during participant interviews). However, the use of glass whiteboards and LED screens to share student work was not done in every class session. Moreover, there were a few unique aspects concerning some of the participants. For instance, Dr. Smith's introductory biology course was administered *via* a wiki site in conjunction with the course web site. Additionally, he also used a class blog as a forum to further explore topics in his course. Each student was expected to contribute to the class blog by writing two full blog posts on news stories relating to class topics and commenting at least once a week on existing blog posts. In the case of Dr. Baker, her advanced chemistry course was designed as a flipped classroom. Therefore, she video-recorded all of her class lectures using lecture capture software (provided by the university IT services) and uploaded them onto the course website for her students to

view before class. Hence, her class sessions were primarily dedicated to working on inquiry-guided activities.

4.1.1.1 Classroom observations for Dr. Smith

Dr. Smith's class sessions had the general structure shown in figure 4-1. Dr. Smith introduced the main concepts of the day *via* a mini-lecture, usually at the beginning of the class session. Students were then allowed to work in their groups while he walked around the classroom to help answer student questions. At the end of the allocated time for the activity, he asked each group to report out their findings to the class. At this point, he encouraged the entire class of students to participate in a whole class discussion and took the time to reinforce or clarify the material or to introduce new material. A given class session had multiple parts to the activity, hence several rounds of small group work and whole class discussions could be seen.

On observation day 1, Dr. Smith talked about 'Species and Speciation'. He employed a web-based interactive learning tool for simulating concepts applicable to evolution of species and speciation. He also brought several specimens of insects and spiders to introduce the concepts of 'speciation'. Further, he used the document camera to report out his students' answers regarding the identification of insect and spider specimens. Table 4-3 summarizes the instructional strategies, technologies and learning space features Dr. Smith utilized during his first classroom observation. Additionally, figure 4-2 depicts the percentage time allocations for each classroom event from Dr. Smith's first classroom observation.

On observation day 2, Dr. Smith continued talking about 'Species and Speciation' and continued to use the same web-based simulation tool. Table 4-4 summarizes the instructional strategies, technologies and learning space features Dr. Smith utilized during his second classroom observation. Additionally, figure 4-3 depicts the percentage time allocations for each classroom event from Dr. Smith's second classroom observation.

On observation day 3, Dr. Smith talked about 'Biogeography'. On this day, he asked his students to use the glass whiteboards to draw phylogenetic trees and share them with the rest of the class. Towards the end of the class, Dr. Smith decided to have students watch an instructional video about extinction events on Earth (from PBS NOVA) in class. Dr. Smith experienced some technical trouble during this class session with the class audio system. He tried to troubleshoot it by himself and later contacted the IT services about the issue. Towards the end of the class session, two persons from the IT staff arrived and discussed the issue with Dr. Smith. Table 4-5 summarizes the instructional strategies, technologies, and learning space features Dr. Smith used during his third classroom observation. Additionally, figure 4-4 depicts the percentage time allocations for each classroom event from Dr. Smith's third classroom observation.

4.1.1.2 Classroom observations for Dr. Baker

Dr. Baker's class sessions had the general structure shown in figure 4-5. Dr. Baker led a flipped classroom (she video-taped and uploaded lectures to the course website for her students to watch before class). Therefore her introduction or the 'mini-lecture' at the beginning of the class session was relatively short. Students were encouraged to work in their groups while she and her teaching assistant (TA) walked around the classroom to help answer student questions. Small group work on inquiry-guided activities comprised a significant portion of her class time (50%- 60%). Dr. Baker didn't carry out any structured whole class discussions. Rather, she addressed the class only when there was a common concern that she felt could be informative to the entire class. However, Dr. Baker employed a clicker question at the end of each class session that was based on the main concept/s of the day. 'Clickers' are categorized as an interactive student response system that enables instructors to pose questions and immediately collect and view the responses of the entire class. She used this as an assessment measure to determine her students' understanding of particular concepts.

mini-lecture → [small group work → whole class discussion]$_{iterative}$ → summary/closure

Figure 4-1. General structure of Dr. Smith's class sessions.

Table 4-3. Summary of instructional strategies, technologies and learning space features from Dr. Smith's observation day 1.

Topic of the day: Species and Speciation		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. Specimens of insects and spiders 4. A web-based simulation tool (evolution of species and speciation)	1. Promote small group work (groups of three students) 2. Promote small group discussions as a table (groups of nine students) 3. Access and work on the worksheets on wiki site 4. Promote hands-on learning with the web-based tool and the specimens
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Document camera	1. Promote whole class discussions between students and instructor 2. Report out/share answers concerning the identification of insect and spider specimens

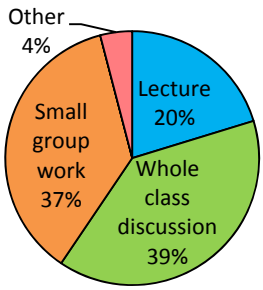

Figure 4-2. Percentage time allocations for classroom events from Dr. Smith's observation day 1.
Note: 'Other' indicates time used for administrative activities- class announcements etc.

Table 4-4. Summary of instructional strategies, technologies and learning space features from Dr. Smith's observation day 2.

Topic of the day: Species and Speciation continued.		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. A web-based simulation tool (evolution of species and speciation) 4. An additional paper-based worksheet	1. Promote small group work (groups of three students) 2. Access and work on the worksheets on wiki site 3. Promote hands-on learning with the web-based tool
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Promote whole class discussions between students and instructor 2. Report out/share answers concerning the worksheets/activities

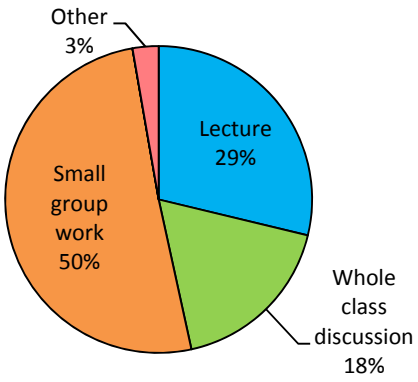

Figure 4-3. Percentage time allocations for classroom events from Dr. Smith's observation day 2.
Note: 'Other' indicates time used for administrative activities- class announcements etc.

Table 4-5. Summary of instructional strategies, technologies and learning space features from Dr. Smith's observation day 3.

Topic of the day: Biogeography		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture Instructional video	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. PBS NOVA video on YouTube	1. Present course materials (lecture slides) to the class 2. Present information (*via* the video) about extinction of species on earth over time
Small-group work	1. Round tables 2. Student laptops 3. Glass whiteboards	1. Promote small group work (groups of three students) 2. Access and work on the worksheets on wiki site 3. Reinforce learned concepts through the drawings of phylogenetic trees on glass whiteboards
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Glass whiteboard	1. Promote whole class discussions between students and instructor 2. Report out/share answers concerning the phylogenetic trees

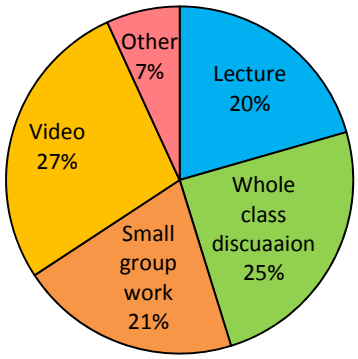

Figure 4-4. Percentage time allocations for classroom events from Dr. Smith's observation day 3.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and troubleshooting technical issues.

On observation day 1, Dr. Baker talked about 'Redox Chemistry'. She employed a web-based interactive learning tool for simulating concepts applicable to redox reactions in electrochemical cells. Further Dr. Baker encouraged small group discussion across tables by moving student groups from one table to another. Table 4-6 summarizes the instructional strategies, technologies, and learning space features Dr. Baker used during her first classroom observation. Additionally, figure 4-6 depicts the percentage time allocations for each classroom event from Dr. Baker's first classroom observation.

On observation day 2, Dr. Baker talked about 'Solid state materials'. She used a web-based learning tool and two YouTube instructional videos to introduce the concepts applicable to crystalline and amorphous solids. Further, she brought molecular models of crystalline structures to promote hands-on learning in student groups. Dr. Baker experienced some technical trouble during this class session with the class audio system. She tried to troubleshoot it by herself during the class but did not succeed. She did not contact the IT services about the issue. Since her students could view the slides and videos on student laptops (on round tables), this technical glitch didn't hinder the student learning experience for this class session. Table 4-7 summarizes the instructional strategies, technologies, and learning space features Dr. Baker used during her second classroom observation. Additionally, figure 4-7 depicts the percentage time allocations for each classroom event from Dr. Baker's second classroom observation.

On observation day 3, Dr. Baker continued talking about 'Solid state materials'. On this day, she brought marbles, paper, tape, and some molecular models of crystalline structures to provide further hands-on learning in student groups. Table 4-8 summarizes the instructional strategies, technologies, and learning space features Dr. Baker used during her third classroom observation. Additionally, figure 4-8 depicts the percentage time allocations for each classroom event from Dr. Baker's third classroom observation.

"mini-lecture" → small group work → clicker question

Figure 4-5. General structure of Dr. Baker's class sessions.

Table 4-6. Summary of instructional strategies, technologies and learning space features from Dr. Baker's observation day 1.

Topic of the day: Redox Chemistry		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. A web-based simulation tool (electrochemical cells)	1. Promote small group work (groups of three students) 2. Promote small group discussions across tables (groups of six students) 3. Access and work on the worksheets on course website 4. Promote hands-on learning with the web-based tool
Clicker question	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Clickers for students	1. Project the clicker question, and % student answer choices 2. Assess student understanding for the day's concepts

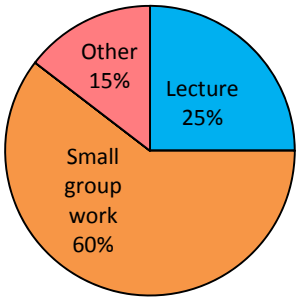

Figure 4-6. Percentage time allocations for classroom events from Dr. Baker's observation day 1.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and clicker question.

Table 4-7. Summary of instructional strategies, technologies and learning space features from Dr. Baker's observation day 2.

Topic of the day: Solid state materials		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. A web-based simulation tool (crystalline and amorphous materials) 4. YouTube instructional videos (crystalline and amorphous materials) 5. Molecular models (crystalline solids)	1. Promote small group work (groups of three students) 2. Access and work on the worksheets on course website 3. Promote hands-on learning with the web-based tool, instructional videos and molecular models
Clicker question	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Clickers for students	1. Project the clicker question, and % student answer choices 2. Assess student understanding for the day's concepts

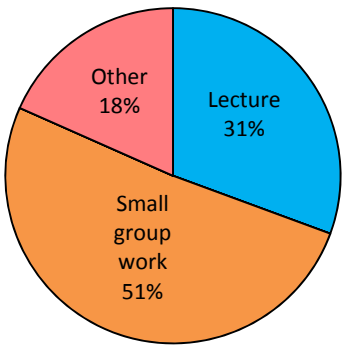

Figure 4-7. Percentage time allocations for classroom events from Dr. Baker's observation day 2.
Note: 'Other' indicates time used for administrative activities- class announcements etc., clicker question and troubleshooting technical issues.

Table 4-8. Summary of instructional strategies, technologies and learning space features from Dr. Baker's observation day 3.

Topic of the day: Solid state materials continued		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. Marbles, paper and tape for making close-packed crystalline solids 4. Molecular models (crystalline solids)	1. Promote small group work (groups of three students) 2. Access and work on the worksheets on course website 3. Promote hands-on learning with learning tools and molecular models
Clicker question	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Clickers for students	1. Project the clicker question, and % student answer choices 2. Assess student understanding for the day's concepts

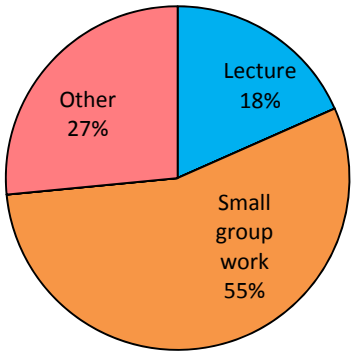

Figure 4-8. Percentage time allocations for classroom events from Dr. Baker's observation day 3.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and clicker question.

4.1.1.3 Classroom observations for Dr. Davis

Dr. Davis's class sessions had the general structure shown in figure 4-9. Dr. Davis introduced the main concepts of the day *via* a mini-lecture, usually at the beginning of the class session. Students were then allowed to work in their groups while she and the TAs walked around the classroom to help answer student questions. Each student group had a team-folder in which the activity for each class session was provided (paper-based activities). Students completed the activity in their groups and put it back in the folder for evaluation purposes. At the end of allocated time for the activity, she asked each group to report out their findings to the class. At this point, she encouraged the entire class of students to participate in a whole class discussion and took the time to reinforce or clarify the material or to introduce new material. A given class session had multiple parts to the activity hence several rounds of small groups work and whole class discussions could be seen. Dr. Davis employed both pre-class and in-class quizzes. Pre-class quizzes were administered online through the course website. In-class quizzes were administered first individually and then as a group using IF-AT (Immediate Feedback Assessment Technique) scratch-off answer sheets.

On observation day 1, Dr. Davis talked about 'Interplanetary travel (primarily concerning Mars)'. She structured this class session to have a debate concerning the potential positive/negative impacts and consequences (such as advances in technology, research, astronaut training, cost etc.) of a manned mission to Mars. She divided her class into three groups (Yes, No, and Maybe in terms of planning a mission to Mars) and provided several websites as key references for the topic. She asked the students to work in their groups and summarize the talking points using the glass whiteboards. After the preparation, she played the role of the mediator to support progression of the debate. At the end of the debate, she provided concluding remarks highlighting the recent developments in the topic with respect to the viewpoints of the physics and astronomy community, other research agencies, funding agencies, and government. Towards the end

of the class session, Dr. Davis decided to have students watch an instructional video about the challenges of planning a manned mission to Mars (from PBS NOVA) in class. Table 4-9 summarizes the instructional strategies, technologies, and learning space features Dr. Davis used during her first classroom observation. Additionally, figure 4-10 depicts the percentage time allocations for each classroom event from Dr. Davis's first classroom observation.

On observation day 2, Dr. Davis talked about 'habitability of a planet and exoplanets'. She brought several demonstration tools and models to discuss the concepts of center of mass, Doppler shift, and spectral lines of given elements in the context of detecting stars and planets in other solar systems. She encouraged her students to use the glass whiteboards to report out answers to the activities. Dr. Davis experienced some technical trouble during this class session with the class audio system. She and the other team-teaching members of the course tried to troubleshoot it by themselves but ended up contacting the IT services about the issue. About halfway through the class session, two persons from IT staff arrived, discussed the issue with the instructors and worked on identifying the source of this technical issue. Table 4-10 summarizes the instructional strategies, technologies, and learning space features Dr. Davis used during her second classroom observation. Additionally, figure 4-11 depicts the percentage time allocations for each classroom event from Dr. Davis's second classroom observation.

On observation day 3, Dr. Davis talked about the 'Drake equation'. During this session she also asked her students to use the glass whiteboards to report out their answers to the given activities. Furthermore, she used the document camera to present the approach of solving the Drake equation and clarify confusions regarding some terms of the equation. Table 4-11 summarizes the instructional strategies, technologies, and learning space features Dr. Davis used during her third classroom observation. Additionally, figure 4-12 depicts the percentage time allocations for each classroom event from Dr. Davis's third classroom observation.

mini-lecture → [small group work → whole class discussion]$_{iterative}$ → summary/closure → [in-class quiz]$_{alternative\ days}$

Figure 4-9. General structure of Dr. Davis's class sessions.

Table 4-9. Summary of instructional strategies, technologies and learning space features from Dr. Davis's observation day 1.

Topic of the day: Interstellar Travel- Mars		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. PBS NOVA video on YouTube	1. Present course materials (lecture slides) to the class 2. Present information (*via* the video) about challenges of interplanetary travel to Mars
Small-group work	1. Round tables 2. Student laptops 3. Folders and paper-based worksheets 4. Websites as resources for class debate 5. Glass whiteboards	1. Promote small group work (groups of three students) 2. Promote small group discussions as a table (groups of nine) 3. Work on the paper-worksheets 4. Promote in-depth research of information relevant to the class topic *via* given websites 5. Summarizing talking points for class debate on glass whiteboards
Whole class discussion and Class debate	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Built-in microphones and wireless microphone for students	1. Facilitate class-debate on positive/negative impacts of interplanetary travel to Mars 2. Promote whole class discussions between students and instructor
In-class quiz	1. IF-AT scratch-off forms	1. Assess student understanding for the day's concepts

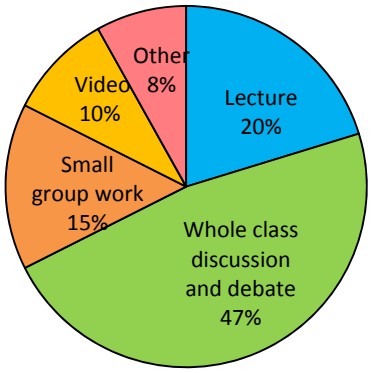

Figure 4-10. Percentage time allocations for classroom events from Dr. Davis's observation day 1.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and in-class quiz.

Table 4-10. Summary of instructional strategies, technologies and learning space features from Dr. Davis's observation day 2.

Topic of the day: Habitability of a planet and detecting Exoplanets		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Hand-held spectrometers 6. Doppler effect demonstration device 7. Model for center on mass demonstration	1. Present course materials (lecture slides) to the class 2. In-depth explanation of the concepts of center of mass, Doppler effect, spectral lines of selected elements (for the identification of stars) using appropriate demonstration tools and models
Small-group work	1. Round tables 2. Folders and paper-based worksheets	1. Promote small group work (groups of three students) 2. Work on the paper-worksheets
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Glass whiteboards	1. Promote whole class discussions between students and instructor 2. Report out/share answers concerning the activity (habitability evaluation of planets in a hypothetical solar system)

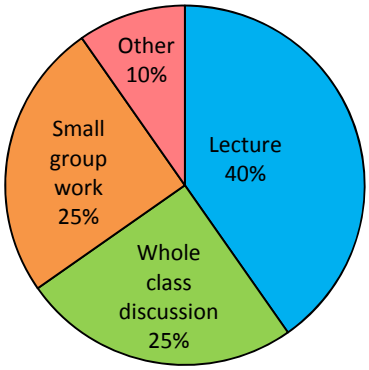

Figure 4-11. Percentage time allocations for classroom events from Dr. Davis's observation day 2.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and troubleshooting technical issues.

Table 4-11. Summary of instructional strategies, technologies and learning space features from Dr. Davis's observation day 3.

Topic of the day: Search for intelligent life in the Universe: the Drake equation		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Folders and paper-based worksheets	1. Promote small group work (groups of three students) 2. Work on the paper-worksheets
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Glass whiteboards 6. Doc-cam	1. Promote whole class discussions between students and instructor 2. Report out/share answers concerning the activity (predicting number of intelligent civilizations in the Universe) 3. Present the approach to solving the Drake equation to the class using Doc-cam
In-class quiz	1. IF-AT scratch-off forms	1. Assess student understanding for the day's concepts

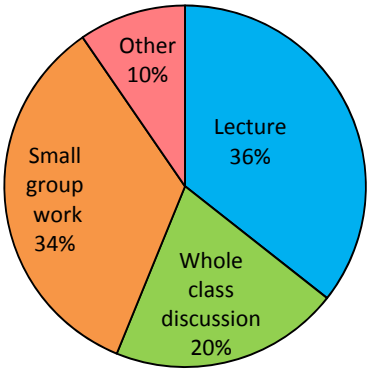

Figure 4-12. Percentage time allocations for classroom events from Dr. Davis's observation day 3.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and in-class quiz.

4.1.1.4 Classroom observations for Dr. Johnson

Dr. Johnson's class sessions had the general structure shown in figure 4-13. Dr. Johnson and Dr. Davis were both co-teaching members of the same introductory science course. Therefore, his profile (instructional strategies, technologies, and learning space features etc.) was very similar to Dr. Davis. He introduced the main concepts of the day *via* a mini-lecture usually at the beginning of the class session. He and the TAs walked around the classroom to help answer student questions while they are working in their groups. He also conducted whole class discussion and took the time to reinforce or clarify the material or to introduce new material. Dr. Johnson employed the same pre-class and in-class quiz systems as Dr. Davis.

In the case of Dr. Johnson, only two class observations were conducted due to scheduling conflicts. On observation day 1, Dr. Johnson talked about 'Modern human origins'. He brought nine skull casts representing various '*Homo*' species. He asked students to work in small groups, thus providing them with hands-on experience in identifying key features of human skulls in terms of predicting which 'Homo' species they represent in the evolutionary process. Dr. Johnson encouraged his students to use the glass whiteboards to draw dendrograms further depicting the evolutionary linkages between early and modern '*Homo*' species. Table 4-12 summarizes the instructional strategies, technologies, and learning space features Dr. Johnson used during his first classroom observation. Additionally, figure 4-14 depicts the percentage time allocations for each classroom event from Dr. Johnson's first classroom observation.

On observation day 2, Dr. Johnson talked about 'Behavioral modernity'. He structured this class session to have a debate discussing the two main theories of the tempo and mode of the evolution of modern human behavior. He divided his class into two groups (representing the two theories) and asked the students to work in their groups and summarize the talking points using the glass whiteboards. After the preparation, he played the role of the mediator to support progression of the debate. At the end of the

debate, he provided concluding remarks highlighting the current viewpoints of the anthropology research community and continued to discuss his opinion along with students' opinions regarding the matter. Furthermore, he used the document camera to present artifacts of three figurines from early human civilizations during this discussion. Table 4-13 summarizes the instructional strategies, technologies, and learning space features Dr. Johnson used during his second classroom observation. Additionally, figure 4-15 depicts the percentage time allocations for each classroom event from Dr. Johnson's second classroom observation.

4.1.2. Summary of college professors' instructional strategies and technologies

Based on the findings primarily from the classroom observations analyzed *via* the enumerative approach, all the participating college professors of this study employed a variety of instructional technologies and learning space features to actively engage their students in classroom activities.

Many similarities were found in terms of the types of instructional strategies and classroom activities utilized among the four participants. These included (1) lecturing or presenting class materials, (2) small group work, and (3) conducting whole class discussions to share ideas and report out findings etc. On average, these college professors' lectured only for about 20% to 40% of the time allocated for each class session while the rest of the time was used to facilitate the student-students and student-instructor discursive activities mentioned above. Moreover, all four participants' used the round tables to promote team-based learning and small group activities in their classes on a regular basis. All four participants used a variety of instructional tools that included both digital technologies (course websites, web-based simulation tools, instructional websites, YouTube instructional videos etc.) and non-digital technologies (whiteboards for reporting out, various models, learning tools and specimens for hands-on learning/demonstration etc.).

mini-lecture → [small group work → whole class discussion]$_{\text{iterative}}$ →summary/closure → [in-class quiz]$_{\text{alternative days}}$

Figure 4-13. General structure of Dr. Johnson's class sessions.

Table 4-12. Summary of instructional strategies, technologies and learning space features from Dr. Johnson's observation day 1.

Topic of the day: Modern Human Origins and DNA		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Folders and paper-based worksheets 3. Nine skull casts of various '*Homo*' species 4. Glass whiteboards	1. Promote small group work (groups of three students) 2. Work on the paper-worksheets 3. Promote small group discussions as a table (groups of nine) 4. Promote hands-on learning with the skull casts 5. Reinforce learned concepts through the drawings of phylogenetic trees on glass whiteboards
Whole class discussion	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Nine skull casts of various '*Homo*' species 6. Glass whiteboards	1. Promote whole class discussions between students and instructor 2. Justify the identification and differentiation of given skull casts 3. Report out/share answers concerning the activity of drawing dendrograms for '*Homo*' ancestors

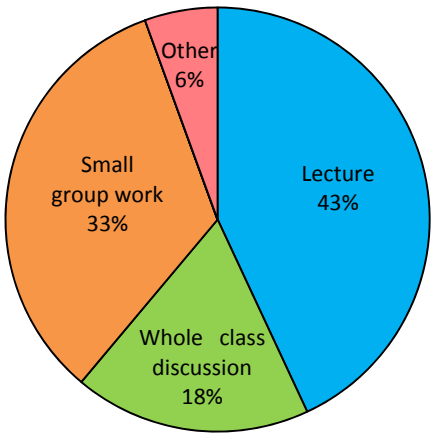

Figure 4-14. Percentage time allocations for classroom events from Dr. Johnson's observation day 1.
Note: 'Other' indicates time used for administrative activities- class announcements etc.

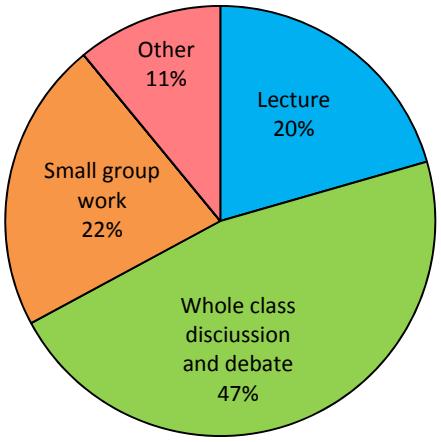

Figure 4-15. Percentage time allocations for classroom events from Dr. Johnson's observation day 2.
Note: 'Other' indicates time used for administrative activities- class announcements etc. and in-class quiz.

Table 4-13. Summary of instructional strategies, technologies and learning space features from Dr. Johnson's observation day 2.

Topic of the day: Behavioral Modernity		
Instructional strategies used	**Technologies, IT resources, learning space features, and other materials used**	**Purposes and intended outcomes**
Mini-lecture	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors	1. Present course materials (lecture slides) to the class
Small-group work	1. Round tables 2. Student laptops 3. Folders and paper-based worksheets 4. Glass whiteboards	1. Promote small group work (groups of three students) 2. Promote small group discussions as a table (groups of nine students) 3. Work on the paper-worksheets 4. Promote in-depth research of class topics *via* readings from course website 5. Summarizing talking points for class debate on glass whiteboards
Whole class discussion and Class debate	1. Smart podium 2. Microphone for instructor 3. LED screens 4. Multiple projectors 5. Built-in microphones and wireless microphones 6. Artifacts form early human civilizations 7. Doc-cam	1. Facilitate class-debate on two contrasting ideas for the evolution of modern human behavior Promote whole class discussions between students and instructor 2. Promote whole class discussions between students and instructor 3. Discuss information (*via* Doc-cam) about early human artwork
In-class quiz	1. IF-AT scratch-off forms	1. Assess student understanding for the day's concepts

However, some differences were also found in terms of the types of instructional strategies and classroom activities used by the four participants. For example, Dr. Baker conducted her class as a flipped classroom, and thus 'lectured' minimally. Further, she allocated the majority of her class time to promote problem solving in small groups but didn't employ whole class discussions or a summary/closure at the end. Dr. Davis and Dr. Johnson used class debates as a way of further promoting student discourse. Dr. Smith used a class blog to help his students to relate real world events to class topics. Dr. Baker used clicker questions; Dr. Davis and Dr. Johnson used in-class quizzes to assess student learning regularly. Dr. Baker and Dr. Smith administered their class activities and worksheets online whereas Dr. Davis and Dr. Johnson used the more traditional paper-based activities. These similarities and differences in college professors' instructional decisions and practices were further explored *via* constant comparative method using classroom observations and interviews as major data sources.

4.1.3 College professors' pedagogical reasoning behind their instructional decisions and practices

Overall, college professors' decisions to engage in a given activity or use a given instructional strategy could be grouped into two main categories:

(1) Necessity to promote student engagement with course materials.

(2) Attain self-satisfaction and efficacy by participating in novel and effective instructional strategies.

Each category is explained in detail below.

4.1.3.1. Necessity to promote student engagement with course materials

College professors' intentions to promote student engagement with course materials dominated their decision-making. This learner-centered thinking played a vital role in multiple aspects, from structuring the overall course materials to designing the details of a given classroom activity for a given class session. Stated in other words, their decision-making was built around the learners and the learning process. This category

included six subcategories that seemed to be interwoven. All these subcategories revolved around understanding the learner and promoting active classroom experiences for the learners. The following sections discuss each subcategory in detail and present the relevant evidence from both classroom observations and interviews.

4.1.3.1A. Getting to know the students in their classroom

All four college professors expressed the importance of getting to know their students in their courses. They highlighted the significance of understanding their students' backgrounds, their academic strengths and weaknesses, and the value of the rapport they can develop with their students.

As shown below, during her interview conducted on 05/23/2014, Dr. Baker specifically talked about how the TILE classroom setting helped her to get to know her students well and promoted much more interaction with them.

> *I guess I can address one of the things I really like about it (the TILE setting) was engagement with the students and getting to know the students. It was a huge class I mean it was like 78 students. And in the lecture, I would recognize maybe 10. But I would say I recognize and know the names of at least 70 of the 78 students now. I also think that student engagement was much better so that I had much more of a rapport of students and they are more willing to ask questions than in a lecture based style where you don't really have that.*
> (Interview with Dr. Baker, 05/23/2014)

This student-instructor rapport was also evident during the three observations of her class (conducted on 04/03/2014, 04/17/2014, 04/22/2014) as she walked among the round tables talking to student groups and helping with their activities.

During her interview conducted on 05/21/2014, Dr. Davis also talked about how the TILE classroom setting helped her get to know her students better and develop a significant interaction with them.

> *Well for me, the biggest thing I noticed teaching in a TILE classroom is walking right up to your students and interacting with them in a really different way, I would walk among them (student groups sitting in round tables) and sometimes sit down with them (with the student groups in their tables) and that's a really*

> *different experience. I felt like it was much easier to see and talk to my students.* (Interview with Dr. Davis, 05/21/2014)

This student-instructor interaction was also apparent during the three classroom observations of her class (conducted on 04/17/2014, 04/22/2014, 04/24/2014). She walked among the round tables and engaged in discussions with the student groups while helping them with their questions and activities.

Similar student-instructor interactions were observed during Dr. Smith's three classroom observations and Dr. Johnson's two classroom observations. Furthermore, both of these participants also expressed the same attitude as described for Dr. Baker and Dr. Davis above.

4.1.3.1B. Encouraging student-student, student-instructor discourse

Another common theme that emerged from data analysis is how all four participants worked hard to encourage student-student and student-instructor/student-TA discourse. All four participants' had established a small group structure in their courses (evident from all the 11 classroom observations) and encouraged their students to work in groups. Further, all four college professors' (and TAs for Dr. Davis's and Dr. Johnson's courses) continuously walked among the round tables to answer any student questions and concerns and to provide clarifications or detailed explanations. Additionally, Dr. Davis, Dr. Smith, and Dr. Johnson conducted whole class discussions to promote student-instructor discourse.

As shown below, during his interview conducted on 05/28/2014, Dr. Smith mentioned how the TILE setting helped him promote student-student discussions in small groups and whole class discussions.

> *well I think the arrangement (in the TILE room) certainly does help because, it allows the students to work together and to collaborate and then because everyone can kind of see each other swirl around and allows us to have discussion as a class even when the class size is quite large just something that really not possible in the big lecture halls that I have taught in. I mean I teach (mentions another introductory biology course) which is another big class. It is*

> *around 100 students usually and you can't have discussions. People (students) will answer your questions sometimes but there is no discussion about things.* (Interview with Dr. Smith, 05/28/2014)

His three classroom observations (conducted on 04/10/2014, 04/15/2014, 04/17/2014) also illustrated how he promoted student-instructor, student-student discussions during small group activities and whole class discussions.

As shown below, during her interview conducted on 05/21/2014, Dr. Davis mentioned a similar opinion as to how the TILE setting had helped her promote student cooperation in small groups.

> *I was really trying to focus on the student experience so the learning goals were for them to learn to work together, to learn to try to debunk some of their misconceptions about science and I think that doing that in a group is more effective than just having them individually sit in the lecture and have me tell them this is pseudoscience and this is science, this is the way to think about things.* (Interview with Dr. Davis, 05/21/2014)

Her three classroom observations conducted on 04/17/2014, 04/22/2014, 04/24/2014, showed how her students worked in small groups during class sessions thus corroborating her statement.

4.1.3.1C. Using the technological and learning space features at their disposal to effectively deliver course materials

All four participants mentioned several aspects of technological and learning spaces features that enabled them to effectively deliver course materials to their students. Dr. Baker and Dr. Smith, specifically, talked about how student laptops allowed them to easily deliver and manage daily classroom activities. Dr. Baker, during her interview conducted on 05/23/2014, explicitly discussed the value of having online-activity templates for her students.

> *One thing that was really beneficial for having the technology in the classroom was in terms of the delivery of the worksheets, so I have everything on class website as a template and they (students) had specific dropbox folders and it was*

> *really nice, so I didn't have to print out things and collect things.* (Interview with Dr. Baker, 05/23/2014)

Dr. Smith, during his interview conducted on 05/28/2014, also addressed the benefits of the wiki site he had created to deliver and manage activity templates for his students.

> *The wiki, I wanted to do because I hate wasting paper needlessly, so if you got 70 people (students) in the class and you are printing out something either for each individual or for each group it just terribly wasteful, I wanted to get it all on-line so that it is essentially the same thing but you are not wasting the paper, plus, if they (students) fill out a piece of paper in a group there is one piece of paper and it makes it hard for them to study from that whereas the wiki they can all access at all times, so I thought that was an improvement.*
> (Interview with Dr. Smith, 05/28/2014)

4.1.3.1D. Using the technological and learning space features at their disposal to efficiently manage/ facilitate classroom activities

All four college professors mentioned several facets of technology and learning spaces that enabled them to effectively manage their class sessions and assist their students with the various classroom activities. In this regard, Dr. Johnson made multiple comments about the flexibility of the TILE classroom in terms of conducting different activity types that helped his students to understand the concepts better. In the following excerpt, taken from the interview conducted on 05/23/2014, Dr. Johnson explained his thought process behind bringing skull casts to the lecture session (he had never done this in his lectures before), which is something he usually did only in his lab sections prior to teaching in TILE room. These skull casts were brought to class during Dr. Johnson's second classroom observation conducted on 03/27/2014. There were nine skull casts, enabling each table (~nine students) to examine one cast at a given time. During this observation it was evident how his students engaged in both small group and whole class discussions prompted by these skull casts.

> *I have always felt that 3D objects that you can hold in your hand are far richer than you know certainly than static images but even sometimes more than video on 3D on film because you can actually hold them and you actually can see details and things. I didn't know how it (brining skull casts to lecture) would work*

> *in a classroom and it turned out to work pretty well even though that's what you would do in a lab. But I think therein lies the flexibility of that kind of a classroom (TILE room), you have to figure out what works and you have to mix things up.* (Interview with Dr. Johnson, 05/23/2014)

Dr. Davis also made similar comments about the flexibility of the TILE classroom in terms of conducting different types of activities that enabled her to be creative in designing classroom activities.

> *I like the variety that is offered in the (TILE)room), I typically don't do the same thing every time, I really like the challenge of sometimes having the table work together, sometimes having a team work together, sometimes having every team at the table do the same thing, other times having every team do something different and share. I like the idea that sometimes you use the internet, sometimes you use the laptops, sometimes you don't, So I like that challenge and I feel like I'm very aware of what did they do last time and should try to change it so they don't get bored and because I want them also to see that there is lot of creativity in how you do the activities.*
> (Interview with Dr. Davis, 05/21/2014)

Her preference for being creative and flexible could be observed during all three of her classroom observations (conducted on 04/17/2014, 04/22/2014, 04/24/2014) in which she employed a variety of facets such as student laptops, glass whiteboards, the document-camera, and a variety of technological tools such as website, instructional videos, etc.

Dr. Baker mentioned how the accessibility of student laptops with internet connections enabled her to use web-based simulations to assist her students in understanding important chemistry concepts. She referred to the web-based simulation of redox reactions (used during classroom observation #1, 04/03/2014) during her interview (conducted on 05/23/2014) to showcase her reasoning.

> *It is helpful for students to generate data and so in some of the activities, like in the redox one (classroom observation #1, 04/03/2014), they had a simulation of an electrochemical cell and they had to see what happens when they add various things to that. And they were supposed to then create sort of a table to think critically about that. This wouldn't be possible in a lecture. In order for that to work, you would have to take the whole lecture to a computer lab. I guess you can set it up as a demonstration where the lecturer would be putting things in, but then they (students) are just sitting there staring at it.* (Interview with Dr. Baker, 05/21/2014)

The following excerpt from Dr. Smith's interview explained how he used the learning space features such as the round tables, glass whiteboards, and the document-camera to facilitate classroom activities such as small group discussions and student presentations.

> *This is a course about evolution, the way we set it up is you know intelligent design people and creationists have all these challenging questions for evolutionary biologists and so we give each group (student group) one of those and I tell them to respond to that question. And to prepare for that they need to stay sit in their group and they talk, they make a little power point presentation or they usually draw and write notes and put it on the doc-cam. They also write on the white board when they are making their case sometimes. But you can't do all that in a lecture hall.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Smith's reasoning behind using the various learning space features in the TILE classroom was further evident *via* his classroom observations. Dr. Smith encouraged his students to use glass whiteboards to explain a case study on biogeography and to use the document-camera to explain their answers with respect to identifying various insect specimens. These activities were witnessed during classroom observations #1 (04/10/2014) and #3 (04/17/2014) respectively.

4.1.3.1E. Reflecting on their previous teaching experiences

The four college professors in this study seemed to reflect on their previous teaching experiences (both TILE, non-TILE alike) and use these insights to continually improve their class sessions. The following excerpt from Dr. Davis, captured during her interview conducted on 05/21/2014, highlighted this idea. She explained how her previous teaching experiences encouraged her to conduct her courses in the TILE classroom so that she can elevate student-student and student-instructor interactions in her class sessions.

> *It was my experience in large lecture halls and trying some techniques like clickers and peer to peer problem solving that convinced me. I saw improvements with engagement and when we did small things in the large lecture and I thought*

> *that if you were able to do that in a more elaborate scale in a TILE classroom, that is very effective. That was very eye opening for me to see the level of connection and engagement with the students was much higher in the TILE classroom.*
> (Interview with Dr. Davis, 05/21/2014)

Dr. Baker also explained how her previous teaching experiences led her to embrace the TILE setting and enabled her to flip her classroom to promote student-student and student-instructor interactions. Given below is an excerpt from her interview conducted on 05/23/2014, showcase her thoughts.

> *I have taught this course and this is the fourth time through and the first three times were lecture based course, and one thing I noticed with the students in the lecture based course was that there was a lot of concepts that were hands on or such as point groups or something like that or they really required the students to do problem solving, and you can't really do that in a lecture based format so when the opportunity came up to do that in a TILE room, then I decided to flip the class.*
> (Interview with Dr. Baker, 05/23/2014)

Therefore, it can be stated that reflecting on previous teaching experiences has provided these professors with a rationale to invest more time and energy in innovative, student-centered instructional strategies.

4.1.3.1F. Bringing fresh/novel perspectives to each class session

All four college professors indicated the importance of bringing fresh perspectives to each class session to keep their students motivated and engaged. This idea is nicely captured in the following excerpt from Dr. Johnson's interview conducted on 05/23/2014. In the following excerpt, Dr. Johnson explained how the instructional videos and websites he employed in his class sessions from time to time had helped him create excitement in class as well as introduce the concepts effectively.

> *I sometimes think that even in the classroom you have to mix things up and you have to try different formats you know you can create the excitement in the classroom just by doing things little differently from day to day. So, that has made me consider that possibility in terms of finding short clips and short elements (refers to the instructional videos and websites he has used in his classes) that can*

> *show things visually much better than I can explain them or will allow me to explain while they are seeing it.*
> (Interview with Dr. Johnson, 05/23/2014)

4.1.3.2. Attain self-satisfaction and efficacy by participating in novel and effective instructional strategies

The second category, which was the attainment of self-satisfaction and efficacy by engaging in innovative teaching strategies, was somewhat related to the previous category yet quite unique in its own right. This is because, unlike the previous category, this category was centered on the instructor him/herself. All four participating college professors talked about the self-satisfaction they attained when they saw their learners succeed in a given classroom activity or a given assessment. These college professors' personalization of their teaching practices encouraged them to invest more time and energy on their teaching strategies thus promoting the exploration of novel trends in instructional technologies and strategies. The following excerpt from Dr. Smith's interview (conducted on 05/28/2014) revealed the confidence and self-satisfaction he gained through his teaching in the TILE classroom.

> *Well after the first year, may be the first two years (I was) not super confident. I felt like a few students really got it and some of them didn't. Last year and this year in my class I felt very strongly, increasingly strongly that it has been really effective. Especially this year performance on the exam, performance on the other forms of assessment just the level of discourse we had, in many cases very high. I felt very good about it I'd say, and I think that I'm trying to do better every year and I feel like I'm starting to beat the curve there, let's just say I'm starting to find things that are effective and things that help student learn.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Baker shared her thoughts on how pleased she felt particularly after receiving feedback from her students about the video-recorded lectures that were posted to the class website as a part of the flipped classroom structure. The following excerpt captured during her interview conducted on 05/23/2014 illustrates her self-satisfaction.

> *It (recording and posting lecture videos) was great. Students loved it. I didn't realize how much they would love it. I had several people (students) talk about*

> *how they like that fact that they could watch the lecture before class they may not get everything in it but when they are studying if they had questions they could go back and re-watch the lecture and then start to understand the material much better so that was really good.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Johnson during his interview stated an interesting reasoning. "He indicated that keeping up with advancements in learning space design and digital technology leading to novel instructional technologies motivated him to engage in novel instructional technologies."

> *Well, for my perspective, I thought that it would provide me a way to sort of keep up with where teaching technology is going, so my sense is that there is increasing interest and an increasing push to have TILE classrooms and learning technology incorporated into various kinds of classroom structures, so I just thought it was important for me to sort of be aware what is going on with that to kind of keep up with that. I think it is easy sometimes for more senior professors to perhaps lose sight of where things are happening and so I needed (to keep up with teaching technology) and this (teaching in the TILE room) would give me a structure to do it.*
> (Interview with Dr. Johnson, 05/23/2014)

Dr. Johnson's' comments regarding how experienced college professors may easily lose sight of teaching innovations if they didn't keep up with it is of significance. Teaching in a TILE classroom provided him with a rationale to keep up with recent instructional technological advancements and provided him with the satisfaction of using these novel technologies to promote his students' learning gains. Similar reasonings regarding 'keeping up' with novel instructional technologies and strategies were mentioned in the other three participants' interviews as well.

Additionally, some context-dependent external factors seemed to play a role in these college professors' decision-making process. These factors were primarily related to subject specific concerns of that particular course (breadth/depth of the topics, major/non-major concerns etc.), and the availability of resources (pedagogical, digital,

physical etc.) at the time of course conduction and mainly influenced specific details pertaining to course structure and delivery.

The following quotes from Dr. Baker's interview indicate how her decision-making process was affected by the lack of digital resources, specifically not having adequate licenses to a software program.

> *Earlier in the semester is we tried to use 'Mathematica' to do graphing and I contacted the university and the IT said that 'oh everything is fine' but they forgot to tell me they only have so many licenses, about 20 licenses for 27 groups. So that caused a huge issue because not all the students could do the activity and so because of that I sort of shied away from it.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Johnson during his interview showed his concern regarding students' level of maturity (freshman vs. juniors and seniors) that needed to be addressed with the breadth/depth of the course materials. He referred to the class debates (one class debate was observed during his second classroom observation on 03/27/2015) that he had used in his TILE classroom and deliberated whether they (class debates) are more suitable for introductory or advanced level students.

> *In some ways if it was a class for juniors and seniors than for first years mostly because some of the ways which we ask students to navigate distill material and bring things together and debate it and everything might be better done by students who are more experienced and who already have a broader background and I think the argument can be made both ways. I guess the argument can be made both ways.*
> (Interview with Dr. Johnson, 05/23/2014)

Therefore, as a whole, it is evident from the above findings, the four participating college professors' pedagogical reasoning behind their instructional decisions and practices were guided by two main pedagogical reasoning categories that encompass learner-centered reasoning (necessity to promote student engagement, get to know the students etc.) and instructor- or self-centered reasoning (attainment of self-satisfaction and efficacy).

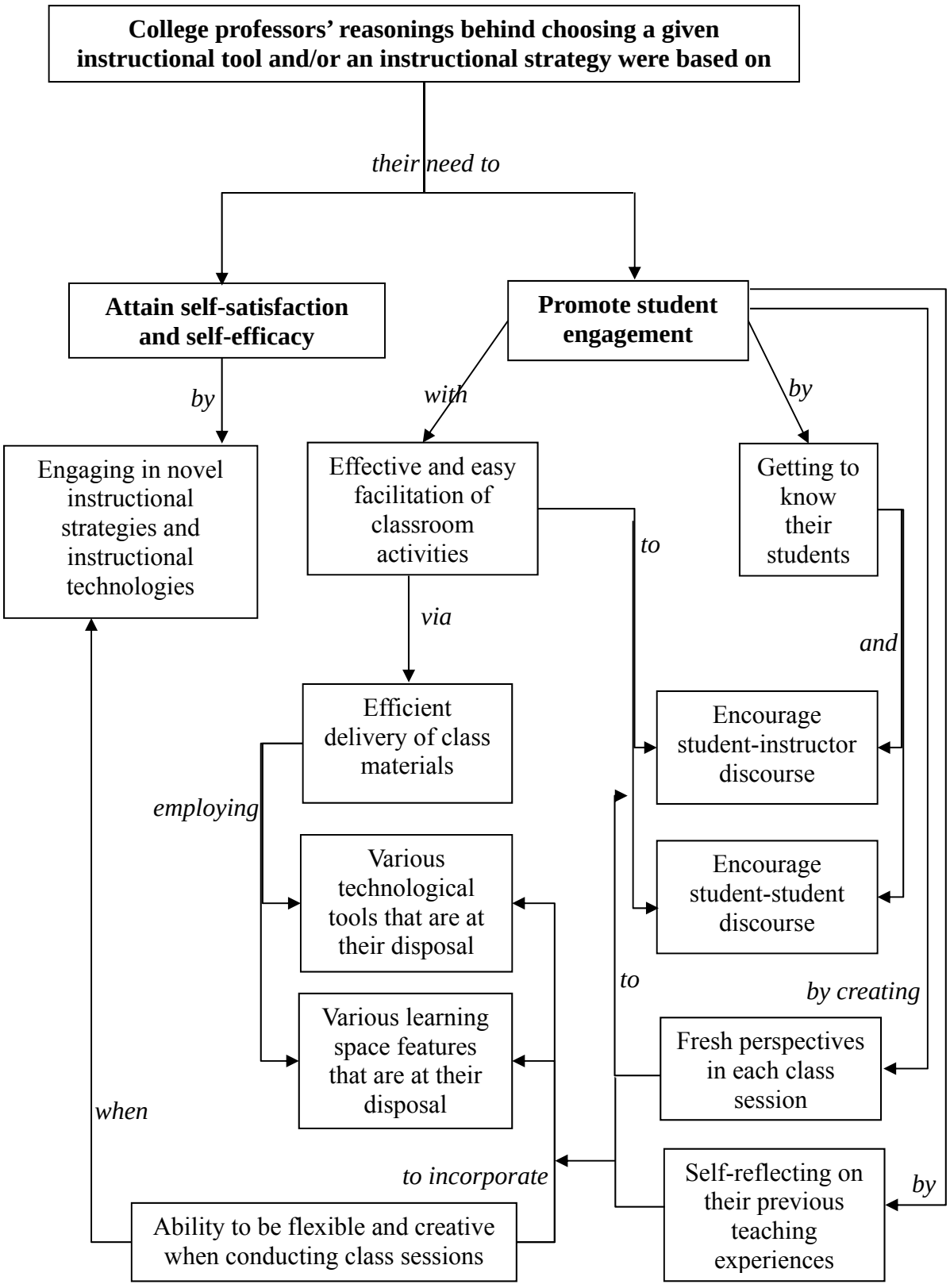

Figure 4-16: A schematic representation of college professors' pedagogical reasoning and decision making process

4.2 Results and findings regarding research question 2

Research question 2 (RQ2) intended to investigate how college professors are influenced by various instructional technologies and learning space features in the TILE classroom setting during their lesson planning, lesson execution, and assessment of student learning. Semi-structured interviews analyzed *via* the constant comparative method were employed as the primary data source in order to formulate answers to this research question. Classroom observations were also used as an additional data source to supplement the formulated answers.

All four participating college professors indicated that their instructional decisions and practices are influenced by various instructional technologies and interactive learning space features they have encountered. These college professors further indicated that these available instructional technologies and learning space features were not only limited to the TILE classroom setting but also included the resources they learned through workshops and colleagues. Overall, the influence of instructional technologies and interactive learning

space features was most prominently seen at the lesson planning stage. Similarly, the lesson execution stage (class sessions) was also greatly influenced by the college professors' awareness of available instructional technologies and interactive learning space features. In contrast, this influence was found to be less prominent at the student assessment stage. All four college professors seemed to rely on traditional assessment strategies regardless of the availability of various instructional technologies and learning space features in the TILE classroom. These findings are addressed in detail in the following sections.

4.2.1. Influence of instructional technologies and interactive learning space features at the lesson planning stage

As reported above, the influence of instructional technologies and interactive learning space features was most prominently seen during the college professors' lesson

planning stage. All four participating professors planned their lessons and activities extensively. The planning process started with the selection of topics for a given day/week. Then they identified the learning objectives or goals for that topics, followed by the formulation of related content and activities to achieve the respective learning goals. The following excerpt from the interview with Dr. Smith represents this finding.

> *Well I mean I try to come up with a general idea. Well first the learning objective or several learning objectives and a general idea in what context I'm going to frame the activity to get to those objectives and then I think about those things in that third step. So I think about whether I would use the white boards or whether I want to have it more of a discussion or primary on the wiki.*
> (Interview with Dr. Smith, 05/28/2014)

The college professors' awareness of various instructional technologies and interactive learning space features came into play when they tried to structure and elaborate the content and activities for the given topics. For example, if the college professor decided that students needed hands-on experiences with a given topic, he/she chose to use a web-based simulation, model kits, specimens, or other learning tools to accomplish that goal.

Specific examples to support this claim can be found from each participant's classroom observations. For instance, Dr. Baker used a web-based simulation to discuss redox reactions during her classroom observation 1 (04/03/2014). Further, she brought marbles and molecular model kits to provide hands-on modeling experiences with respect to the concepts relevant to solid-state materials during her second and third classroom observations (04/17/2014, 04/22/2014 respectively). Dr. Davis brought hand-held spectrometers, a device to explain the Doppler effect, and a model to explain center of mass when she talked about the detection of exoplanets during her second classroom observation (04/22/2014). Dr. Johnson, during his second classroom observation (03/27/2014), brought three artifacts--figurines from three ancient civilizations--to promote the discussion about behavioral modernity in humans. Dr. Smith brought

several insect specimens to the class (classroom observation #2, 04/15/2014) to introduce the concept of speciation. Furthermore, during his interview, he referred to these specimens to indicate how he changed that particular activity over the years.

> *The thing with the insects, talking about what is a species, that was entirely new this year. I just wanted to include that as part of the course so that was completely changed because that was new this year. The thing (activity) with allopatric vs. sympatric speciation, I have changed it little bit each year and the changes have been in the questions I asked them at the end about pulling things together at the end. I felt that is fairly effective.*
> (Interview with Dr. Smith, 05/28/2014)

Further if the college professor decided that students needed to share their opinions and needed to be exposed to other viewpoints regarding a given topic, he/she chose to use the whiteboards to have students report out. A group discussion (involving more than one table), a class debate, or a whole class discussion was also used to accomplish that goal. For instance, Dr. Davis and Dr. Johnson employed class debates to generate productive discussion among students. Dr. Johnson, during his second classroom observation, employed a structured debate about two main theories of tempo and mode of the evolution of modern human behavior (03/27/2014). Dr. Davis during her first classroom observation employed a structured debate about interplanetary travel to Mars (04/17/2014). Furthermore, during her interview, Dr. Davis discussed why she thought the debates were a helpful addition to the class.

> *I think I was surprised as to how well those debates worked out. I'd say more than half of the students said things that were very intelligent and well thought out, I think giving them time ahead of time to prepare their thoughts helped a lot*
> (Interview with Dr. Davis, 05/21/2014)

In another example, Dr. Johnson encouraged his students to use glass whiteboards to draw phylogenetic trees (dendrograms) depicting evolutionary linkages between different "Homo' species (classroom observation #1, 03/25/2014). Similarly, Dr. Smith

encouraged his students to use glass whiteboards to draw phylogenetic trees to explain multiple scenarios of speciation (classroom observation #3, 04/17/2014).

There were instances when the college professors' felt the need for a fresh perspective and therefore changed the class dynamics by incorporating a different set of technologies or learning space features. Some examples included watching a video as opposed to having a lecture, using the document-camera to report out findings as opposed to using the whiteboards etc. Dr. Smith decided to incorporate a PBS NOVA video about mass extinction that took place on earth (classroom observation #3, 04/17/2014). Similarly, Dr. Davis decided to show a PBS NOVA video about challenges of travelling to Mars (classroom observation #1, 04/17/2014). Dr. Johnson mentioned a YouTube instructional video that he decided to show in class about bipedalism (this was on a day other than the two classroom observations). He explained his thought process behind planning to watch the video in class as opposed to asking the students to watch it at home.

> *There are some things that require stopping the video and pointing certain things out, making linkages in the classroom that they (students) can't do when they (students) are watching the video for the first time. Because, I think may be sometimes people (faculty members) think erroneously that that's all they (students) need to do is to watch the video, but that's not true. There are subtleties that happen that they (students) are not going to grasp and slowing the film (video) down and showing and discussing a point might be what is required to get the full sort of impact.*
> (Interview with Dr. Johnson, 05/23/2014)

One other important aspect of this stage was that it was not temporally restricted. In that sense, the college professors constantly reflected on their class sessions, activities, and student responses along with TA feedback to continually modify them. During his interview, Dr. Johnson mentioned how his reflections combined with student feedback prior to the class debates motivated him to employ a structured debate in class.

> *I routinely ask students for comments and to try to generate discussions in class and everything but it mostly just turns out to be a bunch of interesting comments*

> *at the end of the lecture which are fine and students report back that they liked that and they enjoy it. But I do think there was a missed opportunity to not actively structure like a debate from time to time so I wanted to try to start doing that (debate) within the limitations of the materials that I'm trying to get across.*
> (Interview with Dr. Johnson, 05/23/2014)

During his interview, Dr. Smith mentioned how his notes combined with student responses from prior semesters helped him to alter and modify class activities.

> *It's my notes that I have taken about how the course or how that one (activity) went on a particular day. But remember I have all the wiki answers so that I can see what they (students) have written and if the whole class has not understood it (the purpose of the activity) then I'll definitely be wanting to reimagine that activity for next year. I worry and reconsider everything every single part of each activity.*
> (Interview with Dr. Smith, 05/28/2014)

Furthermore, Dr. Baker, during her interview talked about a web resource that she has been using to design classroom activities. However, after utilizing the activity in this semester, she has decided to find a virtual (web simulation) that might suit her better when she does the activity next time.

> *There was one activity we were looking at, closest packing structures, so we had to use marbles. Yeah you can go out and buy marbles for 6 students and it is no problem, whereas I had to go out and buy marbles for 80 students it is a problem it is a little expensive. That's where virtual (simulations) and the technology comes into play because, if I can do that and that is cheap on me.*
> (Interview with Dr. Baker, 05/23/2014)

These experiences combined with their awareness of novel instructional technologies and innovative teaching strategies collectively influenced the planning for upcoming class sessions.

4.2.2. Influence of instructional technologies and interactive learning space features at the lesson execution stage

The influence of instructional technologies and interactive learning space features was also prominent during the college professors' lesson execution stage. The lesson

execution stage was the enactment of the college professors' lesson planning stage. Therefore, the extent to which they decided to structure and elaborate the related content and classroom activities with available instructional technologies and interactive learning space features could be observed during this phase. Examples included bringing and distributing the necessary materials to promote hands-on learning, structuring the class to allocate time to watch a video, or for a debate, report out time with whiteboards, document-cameras etc. Being team-teaching members of an introductory course, Dr. Davis and Dr. Johnson were frequently seen discussing lesson execution ideas with other co-teaching faculty members and TAs (classroom observations for Dr. Davis: 04/17/2014, 04/22/2014, 04/24/2014 and classroom observations for Dr. Johnson:03/25/2014, 03/27/2014). During their interviews, Dr. Johnson and Dr. Davis (conducted on 05/23/2014 and 05/21/2014 respectively) talked about how all the co-teaching members and TAs met weekly to prepare for the course. They also acknowledged how these meetings helped them to better prepare for class sessions. The following excerpt from Dr. Johnsons' interview captures these thoughts nicely.

> *…by and large it was cooperative going back and forth between what I had envisioned and what (mentions the name of a team-teaching member) thought would work and also in Monday planning sessions what some of the other TAs and other faculty members suggested I found those to be particularly useful.*
> (Interview with Dr. Johnson, 05/23/2014)

Dr. Davis also explained how she talked with the TAs at the beginning of the class session and gave them 'heads-up' about the possible activity questions where her students might need extra help.

> *So what I try to do, and this is just from experience, and try to anticipate how long something is going to take students to do. What I like to tell the TAs are "okay these are three places where I think the students are going to struggle so be prepared when they ask you this".*
> (Interview with Dr. Davis, 05/21/2014)

The college professors' main struggle during the lesson execution stage seemed to be time management. Even though they extensively planned their lessons and activities, actual execution revealed unforeseen circumstances on a regular basis (technical glitches, running out of materials, side-tracked by class conversations etc.). It was observed on multiple occasions how these participants struggled to complete the end-of-class quizzes (classroom observation #1 for Dr. Davis, 04/17/2014; classroom observation #2 for Dr. Johnson, 03/27/2014), complete a planned activity (classroom observation #1 for Dr. Smith, 04/10/2014) etc. during their class sessions. During his interview, Dr. Smith talked about how easy it is to lose track of time when you are working on different activities in a TILE classroom.

> *I have a lot of anxiety about just the day to day operation, If you are lecturing, you are just lecturing till you are done, but in these classes (TILE rooms) you kind of have to manage your time really well. So you have an introduction they work on something for a while and may be a little discussion and it is easy to lose track of time and run out of time and I think it is very hard to manage the time effectively.*
> (Interview with Dr. Smith, 05/28/2014)

All of the participating faculty members relied heavily on their previous experiences and instincts/judgment to improvise and be pro-active in the classroom. During her interview, Dr. Davis discussed how she is comfortable being flexible about improvising a class activity when needed and being pro-active.

> *I like to be able to go around the room and kind of assess for myself where people are at and to let them have the opportunity to tell me "hey we need a few more minutes"…I think I'm pretty flexible about that. I'm very comfortable changing an activity on the spot. I'm very comfortable having students stop at a certain point or go ahead. What's not fun in the TILE classroom and what fails is that when the faculty and TAs are unprepared or not willing to think on their feet because then the students lose confidence in the whole process.*
> (Interview with Dr. Davis, 05/21/2014)

Following quote from Dr. Johnson's interview also states how he anticipated spontaneity in his class sessions and prepared to improvise at those situations.

> *You can't get rid of all the spontaneity you know there is spontaneity in classroom and in learning situations that can't be controlled and can't be planned for and you know the things like making a point because a student raises some important issue that you hadn't anticipated, you have to be nimble and you have to be able to make adjustment on the fly. I think we need that flexibility sometimes. So we have the lesson plan, if it goes a little different but if it is going well, who cares what the original plan was, let's be flexible within reason of course.* (Interview with Dr. Johnson, 05/23/2014)

Moreover, technical issues pertaining to digital technologies were observed to be a fairly common encounter in college professors' lesson execution stage. All the participants, except for Prof. Johnson, dealt with some kind of a digital technological issue during one or more occasions of their classroom observations (classroom observation #2 for Dr. Baker on 04/17/2014, classroom observation #3 for Dr. Smith on 04/17/2014, classroom observation #2 for Dr. Davis on 04/22/2014). It was also observed that the college professors heavily relied on their previous experiences to either try to solve the issue, by-pass the issue, or contact technical support staff. The following excerpt from Dr. Davis's interview illustrates how she expected technological obstacles and prepared to improvise at such situations.

> *I'm also flexible, if the technology doesn't work we can do things on the board (refers to whiteboard) I have had many times when my lecture or video have failed in a lecture hall and you have got to move on and I think just that experience has given me confidence that you know if it all fails you just talk about the material or write things on the board, it is not the end of the world* (Interview with Dr. Davis, 05/21/2014)

As mentioned in section 4.2.1, since the lesson planning stage was not temporally restricted, the college professors were observed to be engaging in lesson planning during the lesson execution stage, continually reflecting on the execution process itself. The following statement from Dr. Smith's interview provide an example to support this claim. He explained how he continually refines a given activity depending on student responses and his reflections.

> *I have changed that one (Biogeography activity- classroom observation #3) quite a bit and I'm still not really happy with it, I wanted to use something where they (students) are using the evidence and trying to figure out the history like a biogeographer would do, I really want it to be them (students) thinking about all the different possibilities and then narrowing them down until they (students) get to an answer that most people (students) have, I mean this year it was getting closer to that but I'm still not happy with it.*
> (Interview with Dr. Smith, 05/28/2014)

All in all, flexibility with the classroom activities, ability to be pro-active, and improvising based on the circumstances seemed to be key skills that these college professors depended on in order to successfully conduct their lesson execution stage.

4.2.3. Influence of instructional technologies and interactive learning space features at the student assessment stage

The influence of technology-infused interactive learning spaces seemed to be least prominent at the student assessment stage mainly due to the college professors' reliance on traditional summative assessment strategies. All the participants displayed a somewhat scattered knowledge base concerning the purpose and process of formative assessment. Furthermore, each college professor had varying levels of familiarity and experiences with formative assessment. All the participants used activities related to formative assessment on a regular basis (classroom activities, reporting out, clickers etc.) but either lacked the awareness or didn't always view them as potential opportunities for formative assessment. For example, Dr. Baker's choice of using clicker questions at the end of the class seemed more of a conclusion to that particular topic. The following excerpt captured during her interview conducted on 05/23/2015 indicates her thought process behind using clickers.

> *And then I did clicker questions to do a bit of assessment at the end and just to make sure people are understanding things and clickers were great, worked almost every time and then it was nice because I could save time again by directly taking from that and putting it to the course website and it was already graded for me.* (Interview with Dr. Baker, 05/23/2014)

According to the three classroom observations conducted on 04/03/2014, 04/17/2014, 04/22/2014, it was evident that she didn't always follow up with the answers or with the student response distribution to the given clicker questions. Furthermore, it was also evident from the classroom observations that her students always perceived that the clicker question was a sign that the class session had come to an end.

In another example, Dr. Smith's blog was a way to get the students excited about the relationship between real world events and class topics and generate a discussion among the students. Yet, whole class discussions regarding students' blog posts were not followed up in-class in a regular manner. Thus, Dr. Smith viewed the blog primarily as a writing assignment and as a summative measure of student understanding and awareness of a real world topic to course topics. The following statement from his interview explains his rationale for using the blog as a writing assignment.

> *Well, I wanted to have a writing assignment, I wanted to have them write and express themselves and use what they have learned in class to express themselves a little bit in writing and I didn't want to have a formal writing assignment because I don't think students like that so much and wanted them to write about something that was interesting to them. The people (students) who did interact (posted and commented on the blog) and I felt like in many cases it is quite a high level and most importantly, they were thinking about it outside the class which was really good.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Davis's and Dr. Johnson's use of pre-class quizzes seemed to be a good example of formative assessment in the sense that they were utilizing student responses from the pre-class quizzes to modify their mini-lectures (put more/less emphasis on given concepts). However, the end-of-class IF-AT quizzes didn't serve the same purpose mainly due to the fact that these quizzes conveyed the end of the class session for the students, which was similar to Dr. Baker's case with clicker questions. This was evident from classroom observations conducted on 04/17/2014 and 04/24/2014 for Dr. Davis and 03/27/2014 for Dr. Johnson respectively.

However, daily discussions in the classroom and report-out using whiteboards and document-cameras prompted the college professors to modify or alter their instructional strategies. Feedback from TAs regarding the grading of classroom activities also informed the college professors of their students' learning process. Moreover, these college professors seemed to gather more information during one-on-one discussions with student groups while walking among the round tables (all 11 classroom observations collectively support this claim as all four participants took time to walk around the classroom and engage in discussion with student groups during their daily class sessions). These interactions also motivated them to modify or alter their instructional strategies. All in all, it was difficult to figure out whether these behaviors counted as lesson planning, self-reflection, formative assessment or a combination in these college professors' minds. Interestingly, during the interviews, all the participants acknowledged some of the lost opportunities of formative assessment and seemed to brainstorm about potential opportunities for future courses. Dr. Davis's comments on the types of formative assessment measures revealed her understanding of the purposes of formative assessment.

> *I think that was the only example (refers to pre-class and end-of-class quizzes) I can think where we actually assessed their learning. I guess the activities (refers to daily classroom activities) were a form of assessment and they weren't just participation, so I think we were constantly assessing them but there were still lot of traditional assessment on pencil and paper (refers to mid-term, end-term exams and other traditional writing assignments) individually.*
> (Interview with Dr. Davis, 05/21/2014)

Dr. Smith's comments on the types of formative assessment measures also revealed his thoughts on formative assessment.

> *On the last couple of days of the class, there are informal discussions about evolution generally and we talk about these big ideas that relates to biology and science and I allow the students to sort of have this debate or conversations in the class and I feel like that gives me a way to assess their level of knowledge and their comfort with the material. It is not a formal assessment but for me it feels*

> *like an assessment because I'm able to see what they know and see what they don't know and sometimes it is surprising.*
> (Interview with Dr. Smith, 05/28/2014)

However, both these comments further indicated the scattered nature of these college professors' knowledge base concerning the purpose and the process of formative assessment. Therefore, these findings signify that these college professors are in need of professional development support in the area of effective student assessment strategies.

4.3. Results and findings regarding research question 3

Research question 3 (RQ3) intended to explore these college professors' overall perception of instructional technology use and learning space feature use in their undergraduate classrooms. This research question formulated answers concerning the benefits and the challenges of teaching with instructional technology in interactive learning spaces. Furthermore, it also explored the types of personal- and professional-development support college professors need in order to make well-informed decisions regarding their innovative instructional practices. Semi-structured interviews analyzed *via* the constant comparative method were employed as the primary data source in order to formulate answers to this research question. Classroom observations were also used as an additional data source to supplement the formulated answers.

Overall, all the participating college professors perceived the instructional technologies and learning space features in TILE classrooms to be greatly beneficial. This beneficial nature was mainly attributed to the multitude of learning space features and instructional technologies that were at their disposal, thus enabling them to engage in an assortment of classroom activities to elevate student learning. However, all the participating college professors described several challenges associated with conducting classes with the instructional technologies and learning space features in TILE classrooms. These challenges primarily revolved around the difficulty of deciding on useful instructional strategies and designing effective classroom activities, revealing these

college professors' limited awareness of student-centered pedagogy. To address these challenges, all the participating college professors indicated that they need additional professional-development support and resources in terms of creating efficient classroom activities that lead to elevated student learning gains. Furthermore, these college professors indicated the value of being recognized by their colleagues and departments for their involvement in scholarship of teaching. These findings are addressed in detail in the sections below.

4.3.1 Benefits of instructional technologies and interactive learning spaces

These college professors' perceived benefits of instructional technologies and learning space features in TILE classrooms could be grouped into three main categories:

(1) Elevate student discourse by facilitating student-student and student-TA/instructor interactions

(2) Enable the efficient administration and management of various classroom activities to promote student engagement with course materials

(3) Allow college professors to be flexible and creative when designing class sessions *via* the availability of various learning space features and instructional technological tools at their disposal

Mirroring the categories formulated in RQ1 (pedagogical reasoning), the first two categories here were found to be centered primarily on the learner and the learning process, thus termed as learner-centered benefits. Although related to the first two categories, the third category was found to be more aligned with instructor him/herself, thus termed instructor- or self-centered benefits. These three categories are discussed in detail with relevant evidence in the following sections.

4.3.1.1. Elevate student discourse by facilitating student-student and student-TA/instructor interactions

All four participants acknowledged that the round table structure of the TILE classroom was invaluable to facilitating the small-group or team-based activities in their

courses. Therefore the opportunities provided by the learning space design to increase the student-student and student-instructor/TA interactions was viewed to be of great importance. Dr. Smith expressed his opinion about how the learning space design helped him to structure small-group activities to promote interaction among student teams. The following statement from his interview conducted on 05/28/2014 showcases his opinion. This was supported by the observation that Dr. Smith's students were working in small groups at round tables while doing the activities (via the wiki site) during his three classroom observations conducted on 04/10/2014, 04/15/2014, 04/17/2014 respectively.

> *I think that working in groups talking to your peers figuring things out in conversation with your fellow classmates is made possible by the structure of the room. I guess it is that just in any class, they wouldn't be able to work in groups on the wiki thing (classroom activities given in wiki site). That's the, so it's really the structure of the room that allows me to do that effectively.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Davis also expressed her opinion about how the learning space design helped students to engage in small-group activities and promoted communication among students. The following statement from her interview conducted on 05/21/2014 shows her view.

> *I, thinking in particular, a student that was a theater major. Towards the end of the year she was very much engaged whereas at the beginning of the year she wasn't sure whether if it (taking a science course) was her thing and I think TILE classroom helped her and the students like her, because I think in a lecture classroom it is so easy to just either not show up or not participate. So I think the working together in the teams and being accountable to presenting results of the group work to the rest of the class were the best about that room.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Davis had her students working in small groups in round tables while doing the classroom activities. Collaboration between peers in these student groups was observed during her three classroom observations conducted on 04/17/2014, 04/22/2014, 04/24/2014 respectively.

Similarly, Dr. Baker mentioned the increased student-student and student-instructor/TA discourse promoted student learning. She particularly mentioned how it

was convenient for the instructors and TAs to move around the classroom and answer student questions, which enabled students-instructor and students-TA dialogues. The following excerpt from Dr. Baker's interview conducted on 05/23/2014 explains this benefit.

> *I think that it (teaching in the TILE room) is beneficial because a lot of the learning occurs when the students are actually doing those problems (refers to classroom activities). If there is someone around to help and make sure they are going in the right direction and also help them to establish groups to work with. I think that for students that are sort of the average or weaker students, it is much more beneficial. If someone is available to them right there, then they going to ask questions and so I think overall I felt like it worked really well.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Baker and her TA walked around the round tables and answered student questions while the students were doing classroom activities in their small groups. These interactions with students-instructor and students-TA were observed during her three classroom observations conducted on 04/03/2014, 04/17/2014, 04/22/2014 respectively.

4.3.1.2. Enable the efficient administration and management of various classroom activities to promote student engagement with course materials

All four participating college professors attributed the efficient management of classroom activities such as small-group work, class debates, and whole class discussions to the learning space design itself. Furthermore, access to student laptops, internet connection, multiple projectors, and LED screens were also viewed as important digital technologies to effectively deliver course materials and manage classroom activities. During his interview, Dr. Johnson described how he took advantage of the learning space to design classroom activities that incorporated both small group work and whole class discussions. He explained this benefit in the following comment.

> *I liked the way in which the students worked in smaller groups to articulate a point of view and then how we had the larger classroom discussion. Because, I think it led frequently to more thoughtful exchange of ideas. As opposed in a regular classroom, you just ask them (students) what do they think about and they*

> *were often telling you stuff off of the top of their heads and I think going through this initial process (small group discussion first them whole class discussions) where the students discuss the ideas amongst themselves (among small groups) first to be really good.*
> (Interview with Dr. Johnson, 05/23/2014)

Both Dr. Baker and Dr. Smith viewed the IT resources in the room, particularly student laptops with internet connection, to be beneficial primarily in terms of delivering, managing, and collecting classroom activities. During her interview conducted on 05/23/2014, Dr. Baker mentioned *"one thing that was really beneficial for having the technology in the classroom was in terms of delivery of the worksheets"* referring to the online classroom activity templates she designed for her students. Similarly, during his interview conducted on 05/28/2014, Dr. Smith also mentioned "*if they (students) fill out a piece of paper in a group there is one piece of paper and it makes it hard for them to study from that whereas the wiki they can all access at all times"* referring to his online classroom activity templates on the wiki site. During her interview on 05/21/2014, Dr. Davis mentioned the benefit of having different types of technological resources (in the TILE room) at her disposal to make her classroom activities effective; *"I like the idea that sometimes you use the internet, sometimes you use the laptops, sometimes you use the individual screens and a group shows something to the whole class and I find that very exciting."*

Additionally these college professors also acknowledged the role played by these digital technologies while using discipline specific websites, simulation tools, and videos. During his interview (conducted on 05/23/2014), Dr. Johnson mentioned how a video (about bipedalism) he chose to show in class was particularly effective in explaining the concepts behind different gaits cycles.

> *There was one video in particular for the bipedalism module, where we showed the class a modeled human walking that had a sufficiently complex set of modeled muscles included key muscles that were firing and relaxing that you could easily see and you could easily relate to the different cycles of the gaits. and this is one of the best things I have ever seen to illustrate for students how those muscles*

> *function so I thought that was kind of a real treasure and I certainly use that in some of my other classes.*
> (Interview with Dr. Johnson, 05/23/2014)

Classroom observations #1 and #2 for Dr. Smith (conducted on 04/10/2014 and 04/15/2014) showcased his use of a web-based simulation tool to provide hands-on experience for his students about the concepts relevant to natural selection. Furthermore classroom observation #1 for Dr. Baker (conducted on 04/30/2014) showcased her use of a web-based simulation tool to create hands-on experience for her students about the concepts relevant to redox reactions and electrochemical cells.

4.3.1.3. Allow college professors to be flexible and creative when designing class sessions via the availability of various learning space features and instructional technological tools at their disposal

This category is primarily aligned with self-centered benefits for instructional technologies and instructional strategies for these college professors. According to the participants, the ability to be creative while conducting their class sessions provided enriching and enjoyable experiences to them. Not restricting themselves to lecture throughout the class session gave them fresh perspectives in terms of using class time efficiently to interact with their students. Thus the ability to be flexible and creative enabled college professors to widen their beliefs about teaching and learning. Ultimately, this creativity and flexibility combined with the fruitfulness of their innovative instructional strategies provided a sense of satisfaction and efficacy to these four participating college professors.

Dr. Smith expressed his eagerness about conducting class sessions in a TILE classroom. Following quote from his interview (conducted on 05/28/2014) captures his excitement well.

> *In my opinion, I think the students learn better, retain that knowledge better, and there is an opportunity for them to really get excited about a subject in a way that*

> *it is harder to inspire it in a lecture. I'd also say that it is also fun for me to teach in a room (refers to TILE room) like that.*
> (Interview with Dr. Smith, 05/28/2014)

Similarly, Dr. Baker also expressed her enthusiasm about conducting class sessions in a TILE classroom. The following comment from her interview (conducted on 05/23/2014) presents her thoughts about it.

> *I don't like lecturing and so teaching was always more of a burden when you are just doing lectures vs. I had a lot of fun in the TILE room. I was more relaxed in the TILE room. I could interact with the students I could see more learning going on. It wasn't just me on the front talking to students and seeing them completely unengaged which is kind of demoralizing in a way you know.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Johnson talked about also his enjoyment regarding the class-debates he decided to do in the TILE classroom (one class debate was witnessed during classroom observation #2, 03/27/2014). The following comment from his interview (conducted on 05/23/2014) explains his thoughts behind the effectiveness of the class debates.

> *I found myself in particular enjoying the structured debates that we had and I got a sense that the students enjoyed them as well. I found the discussions to be really good and point-counterpoint kind of dynamics.*
> (Interview with Dr. Johnson, 05/23/2014)

The learner-centered benefits and instructor-centered benefits, illustrated in figure 4-17, were found to be influencing each other. Particularly, these learner-centered and instructor-centered benefits are linked to these college professors' self-satisfaction and efficacy functioning as a feedback loop.

4.3.2. Challenges of using instructional technologies and interactive learning spaces

These college professors' perceived challenges associated with conducting classes with the instructional technologies and learning space features in TILE classrooms could be grouped into four main categories:

(1) Difficulty in designing effective classroom activities,

(2) Difficulty in managing healthy small-group dynamics,

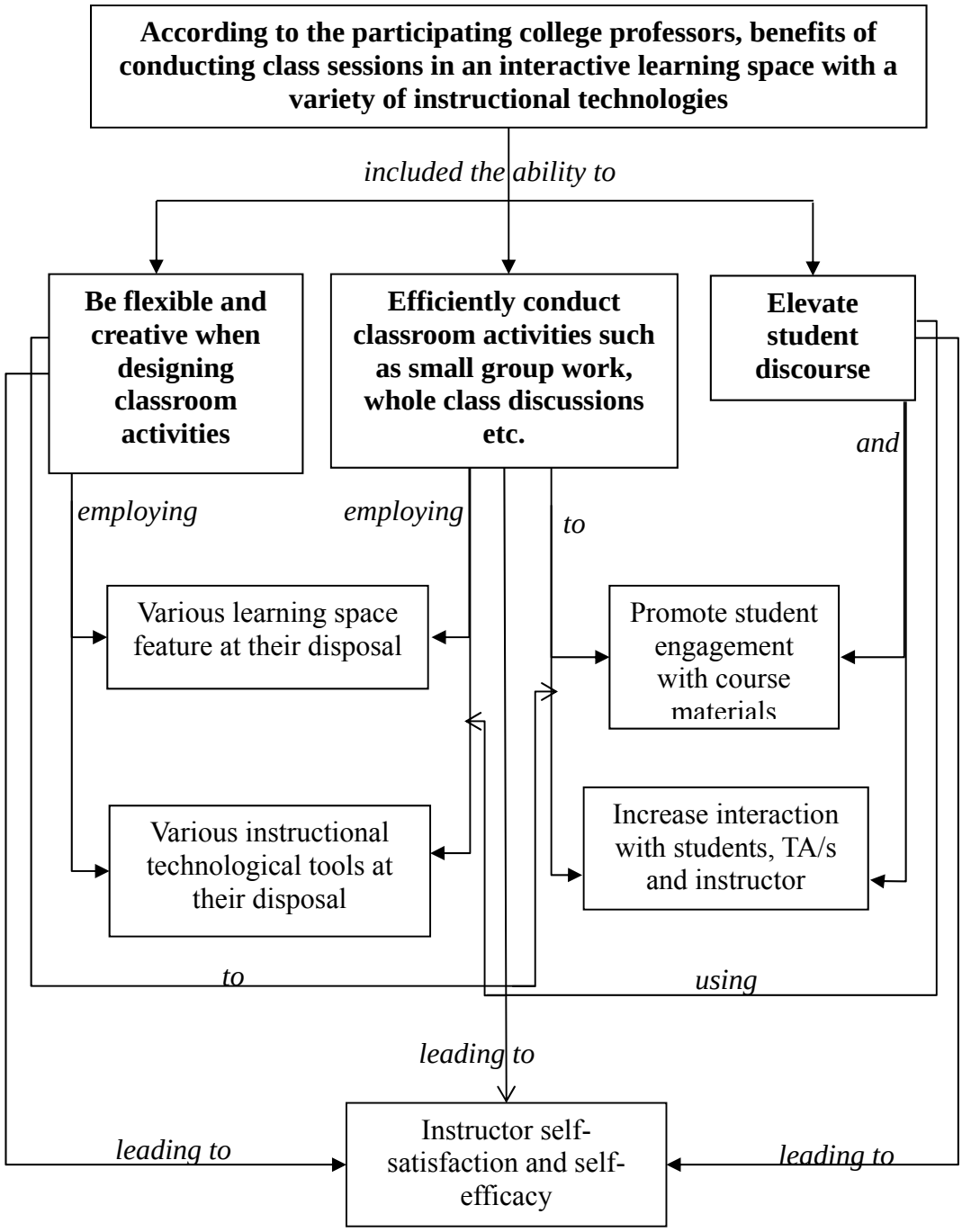

Figure 4-17: A schematic representation of college professors' perceived benefits of instructional technologies and interactive learning spaces.

(3) Deciding the optimum use of instructional technologies and learning space features in a given class session/class activity and,

(4) Lack of recognition and appreciation from their colleagues, department, and institution for investing in novel teaching strategies.

The first three categories above are found to be concerned with the learner and the learning process, thus termed as learner-centered challenges. These three categories seemed to have arisen due to college professors' limited familiarity with student-centered pedagogy and related instructional strategies. Furthermore, these college professors' limited awareness of how to gain access to and use novel digital technologies and other learning tools seemed to be another contributing factor. The fourth category is distinct in the sense that it is primarily concerned with college professors' professional recognition and growth, thus termed recognition-centered challenges. All the four participating college professors expressed their concern with the lack of recognition by their departments and colleagues with regards to their involvement in innovative teaching strategies and scholarship of teaching. All four categories are discussed in detail with relevant evidences in succeeding sections.

4.3.2.1. Difficulty in designing effective classroom activities

All four participants displayed a somewhat scattered knowledge concerning student-centered pedagogy. Similarly, all of them also displayed varying levels of familiarity and experiences concerning the related innovative teaching strategies such as inquiry-guided learning, team-based learning, etc. The following excerpt from Dr. Davis's interview indicated her concerns in terms of deciding the depth and breadth of activities along with their purpose in accomplishing the learning goals.

> *I think the biggest challenge is designing the activities and it takes a lot of time and it takes a lot of trial and error and if anything I think our activities are too shallow, I think there could be room for making them more challenging, making them go a little bit deeper, but it takes time to decide what it is that you want them to do.*
> (Interview with Dr. Davis, 05/21/2014)

The following comment from Dr. Smith's interview voiced the same concern as Dr. Davis's about designing effective activities.

> *I'd say the primary challenge is designing activities that effectively communicate a bigger concept that aren't just busy work. Because it is easy to make an activity where they just fill in the answers and I'm constantly trying to reevaluate the things that I have used in previous years to see if they are really doing what I want them to do.*
> (Interview with Dr. Smith, 05/28/2014)

During her interview, Dr. Baker shared her approach to designing activities and how she has progressed overtime. The following statement from her interview explains her thought process behind designing activities.

> *I will say I didn't really understand the importance of guided learning until I started designing activities because you know when you ask this open ended question like explain this and they will give you the one sentence whereas I suddenly started to realize if I ask them leading questions they will take the time to go through and they will answer one line every time but overall I will get a paragraph of information and so that kind of understanding is helpful.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Johnson shared his experiences in designing activities for his TILE course for the first time. During his interview, he indicated the difficulties he encountered in terms of having to transition from a lecture-based style to an inquiry-guided activity style.

> *So the way I thought I was going to do it (design activities) was, simply take existing lectures and shrink them, you know, but what became very clear to me and it dawned on me that watching other faculty members, I quickly ramped up and thought I can't do that I got to do something different. There were some sort of realization of how much work I was putting into this because I really had to make this transition. But I have to come up with something better than what I thought I was going to do so, I just completely scratched my initial plan I know what my module is, I know what the idea is, but I can't take my pre-existing lectures so I literally made everything up for the first time.*
> (Interview with Dr. Johnson, 05/23/2014)

Participant's comments and experiments within this category indicate the significance of obtaining systematic support regarding student-centered activity designs. Although these participants have valuable ideas and experiments to reflect on for future

class sessions, consistent professional development workshops on classroom activity design can benefit the entire faculty community who lack a firm background for learner-centered pedagogy.

4.3.2.2. Difficulty in managing healthy small-group dynamics

All four college professors revealed their dilemmas concerning the formation of effective small groups (student groups) and the management of healthy group dynamics.

Dr. Johnson shared his concerns about student personalities and their consequences in a small group setting. The excerpt below presents his concern regarding the topic.

> *The main drawback to that (small group work) was you know we often had to work hard to move beyond more vocal of the students who were always willing to contribute and always had something really interesting to say.*
> (Interview with Dr. Johnson, 05/23/2014)

During her interview, Dr. Baker shared her experiences in dealing with troubling group dynamics. The following statement from her interview explains her actions to remedy the issue.

> *What I was little worried about the groups and group dynamics, overall it went very well initially. There were just a couple instances where I had students complained about group members and so midway through the semester I decided to switch the groups around. But in some cases it didn't really alleviate the problem so then this sort of problem student would just be pushed on to another group but I don't know if there is any way around that.*
> (Interview with Dr. Baker, 05/23/2014)

The following comment from Dr. Smith's interview explained how he approached small group formation in his course.

> *Well at the beginning of the semester, I have them fill out an information card and they tell me what their familiarity with the subject matter is, they tell me what their major is, things like that. I try to make sure that they are distributed evenly … I would mix up the group again just to keep it fresh and I would put some thought into who were strong and who were weaker participants. It has been fine but I'm not sure that there is any right way to do it.*
> (Interview with Dr. Smith, 05/28/2014)

Overall, it was evident that these college professors have several concerns regarding student groups and their dynamics.

4.3.2.3. Deciding the optimum use of instructional technologies and learning space features in a given class session/class activity

Added to the above two challenges was the difficulty of deciding the optimum use of instructional technologies and learning space features in a given class session/class activity. This notion was based on their fear of overusing or underusing a given technology or a learning space, which might then hinder their students' learning.

While talking about the challenges he faced in the TILE classroom, Dr. Johnson stated that "*the technology and the environment inherently was not the issue, it is exactly how it was utilized that I think was the issue,"* expressing his concerns about deciding the optimum technological tools for a given classroom activity. Dr. Davis shared her experiences regarding an activity she did in the class that she later thought to be an example of technological tools hindering student learning opportunities. The comment below showcases Dr. Davis's thoughts.

> *I can think of an example of when we had them used a very complicated Excel spread sheet about extinctions and that (Excel sheet) was very sophisticated but I actually think it hindered their learning the big picture there.*
> (Interview with Dr. Davis, 05/21/2014)

Mirroring Dr. Davis's experiences, Dr. Smith also provided an example of a possible hindering of student learning opportunities in his class. The comment below explains the mismatch between Dr. Smith's expectations for his students and his students' competency regarding the use of certain IT resources.

> *They (students) were okay with online stuff (refers to the wiki site and blog). I'm bit surprised in a couple cases I had them download like an Excel spread sheet and fill some things in and some people (students) had no idea how to fill out or put numbers into an excel sheet or you know to open up and edit a PowerPoint and that was quite surprising to me because I thought that everyone knew how to do that.*
> (Interview with Dr. Smith, 05/28/2014)

Moreover, these college professors were not always aware of how to gain access to novel digital technologies or learning tools that might enable them to design and conduct their class sessions more efficiently. Dr. Davis described (shown in the excerpt below) the dedicated IT support in her department, particularly referring to the Instructional Resource Specialist. But she expressed her concerns for the departments who might not have dedicated IT support personnel.

> *We were lucky in our department because we have (refers to the departments' Instructional Resource Specialist) he has always done the training, he has always shown us how to do the technology. Now for departments without people like him, I'm not quite sure how they do it. I mean most of us can figure it out ourselves but I have seen faculty in other departments who don't use technology very often really struggle in the classrooms.*
> (Interview with Dr. Davis, 05/21/2014)

Dr. Johnson voiced his concerns regarding the advancements the faculty community in his field of expertise needs to do with regards to scholarly teaching. The excerpt given below expresses his concerns.

> *To be honest I was surprised and a little bit dismayed how little there (instructional videos and web simulations relevant to his discipline) was out there. I suspect what has happened is that there haven't being enough instructors out there in our field doing exactly this kind of thing (teaching with innovative technologies and strategies) and these kind of classrooms (TILE) to then produce the kinds of web based simulations exercises that we can then use.* (Interview with Dr. Johnson, 05/23/2014)

Overall, the four participating college professors stated the importance of deciding appropriate technologies and learning space features that may enhance student learning. Their concerns indicated hindering student learning either with unnecessary or inappropriate instructional tools, or not receiving adequate support and resources to troubleshoot technical difficulties.

4.3.2.4. Lack of recognition and appreciation from their colleagues, department, and institution for investing in novel teaching strategies

This category primarily revolved around these college professors' recognition-centered challenges. Related to this concern was the lack of appreciation for their teaching excellence when compared to their research excellence. Moreover, difficulties these college professors faced in team-teaching situations with mismatched teaching pedagogies and beliefs were also addressed by this category.

All four participants stated that they have experienced negative impressions concerning the attitudes of their colleagues and departmental administration towards innovative teaching strategies and scholarship of teaching. These included the value given to scholarly teaching when compared to scholarly research in tenure and other promotion procedures. The following excerpts from Dr. Davis's and Dr. Baker's interviews showcase this challenge.

> *I did get a little push back to where the person who was observing me (referring to a peer-observation concerning the tenure process) said "oh you are an assistant professor you need to think about time commitments". But when I explained that part of this written in to one of my NSF grants then he was okay with it.*
> (Interview with Dr. Baker, 05/23/2014)

> *I do think if you are the only person in your department doing it (teaching innovatively) and spending a lot of time doing it (teaching innovatively), it can be difficult too, because professional support. When they (departmental colleagues and administration) are writing a review of your teaching or your annual performance, you need someone who can appreciate that it took a significant amount of time. Otherwise they are going to view this as a negative thing that took away from your research or things like that.*
> (Interview with Dr. Davis, 05/21/2014)

Excerpts from Dr. Smith's and Dr. Johnson's interviews reveal two other challenges that had to do with departmental appreciation and teaching assignment load for faculty members. For example, Dr. Smith's comment below reveals his colleagues attitudes regarding innovative teaching strategies.

> *I think in my department don't necessarily care one way or the other except that it makes the department look good and so they mention it in all these different documents they send to the dean like we have got these professors teaching in*

> *these innovative ways. But I think on an individual basis my colleagues either don't care or outright think it's a stupid thing to do it is just a waste of time*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Johnson's comment below reveals his department's trepidations concerning teaching assignment loads, particularly in the case of team-teaching in TILE classrooms.

> *There are still issues like "Johnson you are only teaching part of it (refers to his co-teaching assignment in TILE) why should you get full credit for it?" So I did have to explain to my chair that well it is more than just my part, I'm attending all the other lectures, I go to weekly planning sessions to make sure that my material does follow with their material, there are things like the field trips. But our DEO is very good about listening to that and had no problem with it. Whether that would be the case for other faculty, I wouldn't know.*
> (Interview with Dr. Johnson, 05/23/2014)

Furthermore, participants who had experiences in team-teaching in traditional classroom settings stated how they experienced push-back from colleagues who didn't have either much appreciation for or lack of awareness regarding student-centered paradigms and related instructional strategies. Dr. Smith's statement below indicated his struggle with regards to team-teaching with faculty members who lack awareness of learner-centered teaching strategies.

> *So, in the course (refers to another introductory biology class) that we team-teach, there is always two professors and so anything I do specially, if it is really good and it improves the class, if the other faculty member doesn't do that, that hurts the other faculty member. So I have consciously tried not to be more exciting dynamic teacher integrating activities into that half of the course, because it'll make that course seems really different, those two parts of the course.*
> (Interview with Dr. Smith, 05/28/2014)

Similarly, Dr. Baker's statement below showed her obstacles with regards to team-teaching with faculty members who lack awareness of innovative instructional technologies.

> *Some of the technology (refers to a certain digital student response system she proposed to use) we can't use unless all the team teachers agree because since we teach a third a third a third. If only one third, they use that technology the*

> *students aren't very happy with that aspect. So we have to get buy in from everyone. It is all dependent on my team-teachers.*
> (Interview with Dr. Baker, 05/28/2014)

Issues regarding professional recognition for teaching excellence seemed to be a widespread challenge that could negatively impact college professors' self-satisfaction and self-efficacy.

4.3.3. Types of desired support

All four participating college professors' desired support could be grouped into two main categories. Both of these categories mirrored the challenges mentioned in section 4.3.2, thus centered on learner-centered support and professional recognition-centered support.

(1) Continuous professional-development support programs and resources that explicitly address student-centered pedagogy, recent advancements in instructional technologies, strategies and educational literature.

(2) Professional recognition and appreciation measures to improve scholarship of teaching and learning within the departmental/institutional structure.

4.3.3.1. Continuous professional development support programs and resources that explicitly address student-centered pedagogy, recent advancement in instructional technologies, strategies and educational literature

This category is concerned with learner-centered support to improve college professors' pedagogical knowledge base regarding designing activities and conducting effective class sessions. It includes six subcategories. All of these subcategories addressed a specific area of professional development support that extended from their perceived challenges. Furthermore, all of these subcategories are collectively concerned with the improvement of students' learning experiences and their learning gains. The following sections discuss each subcategory in detail and present the relevant evidence to support them.

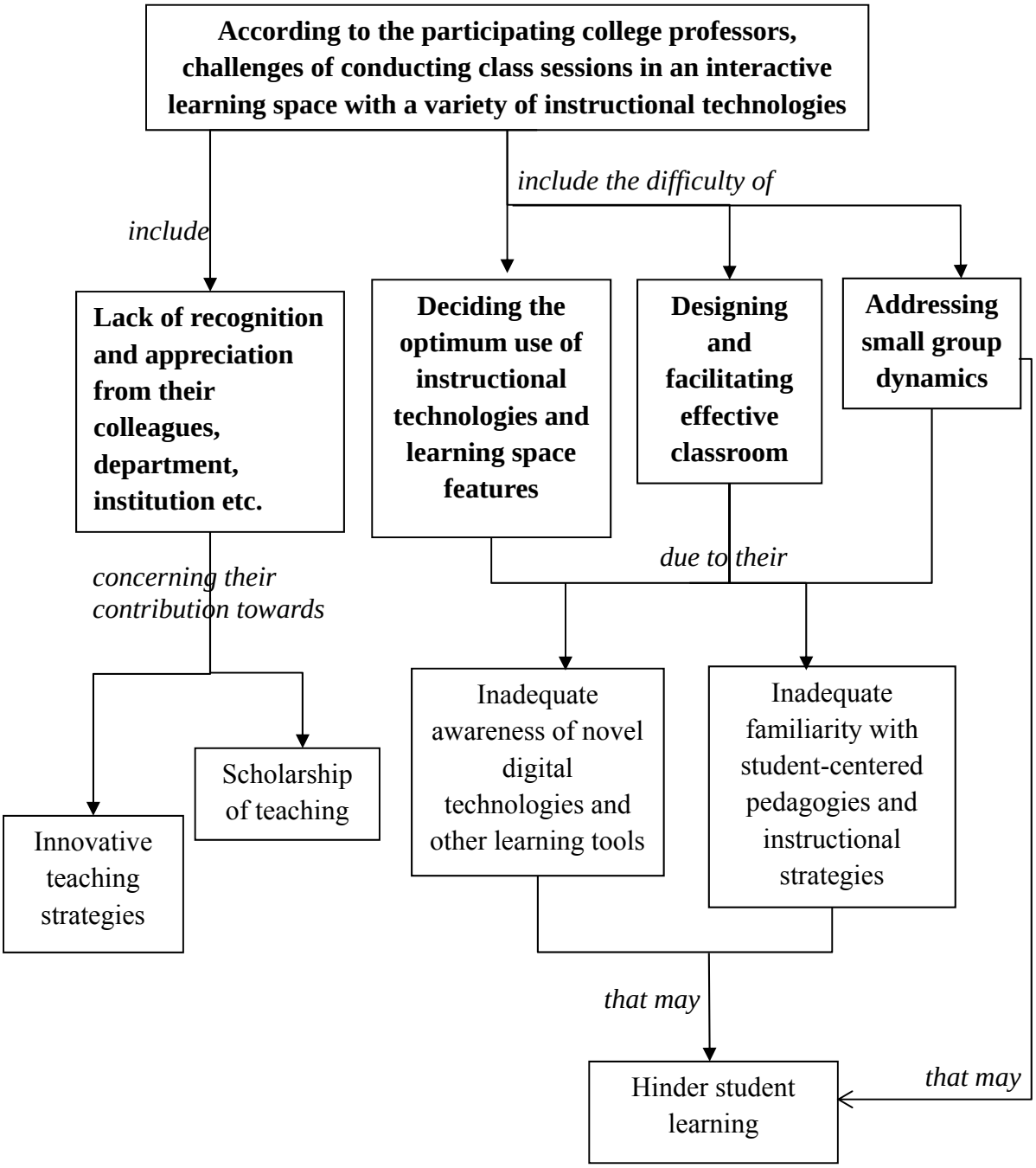

Figure 4-18: A schematic representation of college professors' perceived challenges of instructional technologies and interactive learning spaces.

4.3.3.1A. Professional development programs that explicitly address student-centered pedagogy and related innovative teaching strategies

All four participating college professors exhibited different degrees of familiarity with student-centered pedagogy and related teaching strategies during their interviews and classroom observations. Years of teaching experiences in TILE classrooms, exposure to active learning strategies during their graduate student years, along with exposure to various professional development workshops, faculty communities, and education literature played a big role in their acquirement of learner-centered instructional paradigm. Dr. Baker talked about how a lack of awareness of student-centered pedagogy can impede faculty members who may be considering the transition towards innovative instructional methods.

…but if you didn't have active learning background and I can see a lot of push back from the department, not everyone but quite a few who think this TILE thing is silly and it's not helpful to the students. I don't know I mean maybe there is a subset of people (faculty members) who are sort of curious about it but think it is daunting and overwhelming so they wouldn't know how to set up an active learning activity and even for me it took a little bit of trial and error.
(Interview with Dr. Baker, 05/23/2014)

Therefore, implementing professional development workshops to support implementing student-centered pedagogy and related innovative teaching strategies can help college professors who are considering the transition as well as college professors who have embraced the transition to effectively conduct their class sessions.

4.3.3.1B. Professional development programs that explicitly address effective classroom activity and worksheet design

During the interview, all four participating college professors stated that their biggest challenge in terms of conducting courses in TILE classroom is the design of effective activities and worksheets. Section 4.3.2.1 provides excerpts from all four participants to support this claim. Therefore, implementing professional development

workshops to specifically address topics such as inquiry-guided activity design can help college professors to effectively conduct their class sessions.

In the case of Dr. Davis, she mentioned how a summer workshop focused on inquiry-guided activity design helped her improve on classroom activity writing.

> *Well I think going to that workshop (named the inquiry-guided workshop) last summer was interesting. It was a workshop that started with beginners but people that had some experience really allowed sometime questioning how you develop your activities, so that was very helpful in terms of spending few days thinking about how to develop activities.*
> (Interview with Dr. Davis, 05/21/2014)

Workshops such as this one can provide a firm pedagogical knowledge base and valid rationale for college professors to use when they are designing activities, and may help them save time during the process.

4.3.3.1C. Professional development programs that explicitly address trends in design and use of interactive learning spaces and instructional technologies

During the interviews, all four participating college professors mentioned the significance of having workshops in which faculty members are given opportunities to gain hands-on experience about novel technologies and teaching strategies. Particularly, the two excerpts from Dr. Johnson and Dr. Smith highlight the benefits of such an approach.

> *I think it might be helpful to have a sort of a prepared fake teaching design for a short module where you give it to a faculty member. You give set of instructions and they are pretending to teach some topic. And in order to teach it, they (faculty members) have to cycle through different parts of the technology so they have to say "okay now we are going to switch to doc-cam and I'm going to show you this", and so that would help them (faculty members) to get familiar with moving between different things (technologies in TILE room).*
> (Interview with Dr. Johnson, 05/23/2014)

> *You know the ice breakers, this stuff in my humble opinion is not very useful, so just cut all that part out and also make sure that you have faculty there who are actually demonstrating how the room can be used to its full potential. I'd like to make sure that at least every aspect of the technology that's available in the classroom is exemplified at least once. And that just wasn't the case (refers to a*

> *professional development session he attended) so I found myself after that asking somebody whether I could get into the room (TILE) by my own just so I can familiarize myself with the technology, I never did and I just learned on the fly.* (Interview with Dr. Johnson, 05/23/2014)

4.3.3.1D. Professional development programs that explicitly address the purpose and the process of formative assessment strategies

As mentioned in section 4.2.3, all four college professors displayed a misalignment between lesson planning, lesson execution, and student assessment strategies. Classroom observations and interview excerpts presented in section 4.3.2 explains this misalignment in great detail. This misalignment could be due to the fact that these college professors' insufficiently translated their beliefs about their teaching into their practices. It could also be due to inconsistent beliefs concerning setting up learning objectives, devising learning experiences, and designing student evaluation methods. Therefore, professional development programs specifically targeting this misalignment can help college professors to effectively evaluate their students' academic progress.

4.3.3.1E. Professional development programs that explicitly address effective small group dynamics management strategies

As mentioned in section 4.3.2.2, all four participating college professors expressed their trepidations about small group dynamics. Interview excerpts presented in section 4.3.2.2 showcase these concerns in great specificity. Forming small groups and maintaining healthy group dynamics is critical to the student learning experience as well as for sustaining a pleasant classroom environment for both students and instructor. Therefore, professional development support specifically aimed at forming efficient groups, resolving group dynamic issues, and assigning group roles can help college professors to effectively conduct their class sessions.

4.3.3.1F. Professional development programs that explicitly address ways to gain access to technical support, digital technologies, and other teaching/ learning resources

Dr. Baker and Dr. Davis suggested the prospect of having a dedicated technical support program for the TILE classroom, specifically so that faculty members who teach in them can get continuous support regarding technical issues and finding appropriate resources. The following two excerpts from Dr. Baker's and Dr. Davis's interviews highlight their proposition.

> *It could be good to have someone (from IT services) come in to class (TILE room) a few times a semester, and stay for a half an hour and observe that it (the technology in TILE) is working. I never saw that happen, so I think it would have been because if somebody had come (to the TILE classroom) a few times before that big episode (refers to the technical issue took place during observation day 2, 04/22/2014), they might have gotten to see that building up and they might have able to troubleshoot.*
> (Interview with Dr. Davis, 05/21/2014)

Referring to the same proposition, Dr. Baker further mentioned how a dedicated support system for the TILE room would easily direct the students to a viable troubleshooting option.

> *…so that students in the TILE room could really go to and they (dedicated TILE IT support) understand the actual problem, because that was the issue we really had with the UI capture (refers to the issue with lecture video she addressed in classroom observation #2; 04/17/2014 and #3; 04/22/2014). The students would contact the helpdesk and the helpdesk were random students that didn't have any idea what actually was going on and so instead of being able to contact the TILE IT support they were contacting the random IT support that didn't know what the actual problem was.*
> (Interview with Dr. Baker, 05/23/2014)

4.3.3.1G. Professional development programs that explicitly address research publications documenting innovative teaching strategies and their impact

Participants of this study suggested that the use of research findings regarding effectiveness of novel instructional strategies and technological tools on student learning gains may be a beneficial in terms of conducting professional development workshops for faculty members. The following excerpt from Dr. Baker's interview conducted on 05/23/2014 showcases this suggestion well.

> *Well I will say for the sciences one thing that would be helpful is to have data driven information out there, for chemists in particular, data will drive them to change. So showing that active learning does influence or the TILE classroom do influence learning and outcomes for students I think it is a huge deal and it would be awesome too*
> (Interview with Dr. Baker, 05/23/2014)

Similarly, the following quote from Dr. Smith's interview conducted on 05/28/2014 showcases this suggestion well.

> *Well lot of faculty will say well "yeah this is great but I'm really good at lecturing and I don't need to change anything", but if you show people (faculty members) that there are lots of studies (education research studies) now that are quite convincing. So you show them that, then maybe you have a couple of examples that how it (novel instructional strategy) works. So those things were very convincing things for me as a scientist.*
> (Interview with Dr. Smith, 05/28/2014)

These suggestions were of great value simply because faculty members and administrators are most likely to adopt innovative instructional strategies that are shown to be documented as effective in educational literature in general or discipline-based education literature.

4.3.3.2. Professional recognition and appreciation measures to improve scholarship of teaching and learning within the departmental/institutional structure

The second category is concerned with professional recognition-centered support and included two subcategories. Both of these subcategories addressed the negative impact of undervaluing college professors' ventures in teaching excellence by their respective departments and colleagues. Furthermore, participating college professors indicated the importance of having teaching and learning support communities either within the department or the institution that enables them to share their teaching experiences and exchange novel ideas and resources. The following sections discuss each subcategory in detail and present the relevant evidence to support them.

4.3.3.2A. Implementation of various measures to identify and support adoption of innovative teaching strategies

The four participating college professors highlighted the value of departmental and institutional personnel (administrators, staff and faculty alike) getting familiarized with novel instructional strategies, thereby encouraging the entire community to embrace effective teaching interventions. This is of great importance simply due to the fact that the effectiveness of a given teaching intervention can be elevated when it is disseminated among the community. Propagation of an innovative teaching intervention helps faculty members foster discussion about it and share their suggestions and comments to improve its efficacy. The following excerpt from Dr. Davis' interview nicely captures this proposition.

> *So the DEO of my department and several colleagues were there with me in that workshop (refers to the TILE workshop she attended) and that I think is absolutely critical because in my experience here, departments that have not engaged with the TILE classrooms yet is partly because the leadership probably doesn't understand what they are. So one of the best ways for the chairs of departments or the heads of teaching, if that person is engaged then they can suggest a faculty "this is something you might want to think about, I could see that working well in these classes".*
> (Interview with Dr. Davis, 05/21/2014)

Furthermore, Dr. Smith stated that "*I get a lot of positive reinforcement from the center for teaching and ITS*" referring to the help and encouragement he obtained from the teaching center and the information technology service within the institution.

4.3.3.2B. Implementation of various measures to recognize and appreciate college professors' investments in scholarship of teaching and learning

Participants of this study also proposed some possible ways to increase department-wide and institution-wide awareness of the student-centered paradigm and related instructional strategies. These included the formation of faculty mentoring communities, and faculty teaching and learning communities to share ideas. Dr. Smith during his interview mentioned how he experienced that there is a growing community of faculty members who are enthusiastic about scholarly teaching and related activities.

> *I'm interacting with people (faculty members) in (mentions three different departments), I think people (faculty members) are really excited about teaching in these rooms (TILE) generally and I feel like there is this growing community of faculty that are excited about teaching in new ways.*
> (Interview with Dr. Smith, 05/28/2014)

Dr. Johnson during his interview, suggested that if the institution can devise programs that inform new faculty members of innovative instructional strategies (TILE rooms in this case) available to them, that can promote their enthusiasm as well as inform them of the appreciation the institution has for scholarship of teaching and learning.

> *When new faculty come here for their orientation it might not be a bad idea to have something geared towards that (refers to a TILE training session he attended) where they would say here at the (university) we put certain amount of money and effort support to the idea of these classrooms (TILE) and we want to talk a little bit about what those are how you might take advantage of those as you develop your own teaching here.*
> (Interview with Dr. Johnson, 05/23/2014)

Overall, both these categories (learner-centered support and professional recognition-centered support) along with their respective subcategories ultimately lead to college professors' intention to conduct effective class sessions in interactive learning spaces with various instructional technologies thus promoting student learning gains.

4.4. Unique aspects emerged from each participant's case

All four case studies provided many recurring themes and patterns that were presented in preceding sections. However, each case presented some unique aspects concerning their overall perception of instructional technology, interactive learning space designs, innovative teaching strategies, and student-centered pedagogy as a whole.

By exploring their cases, each participant could be placed at different points of the instructor-centered paradigm. Put in other words, each participant had different degrees of familiarity with and exposure to the fundamental viewpoints of student-centered paradigm, thus influencing their instructional practices and decisions in distinctive ways.

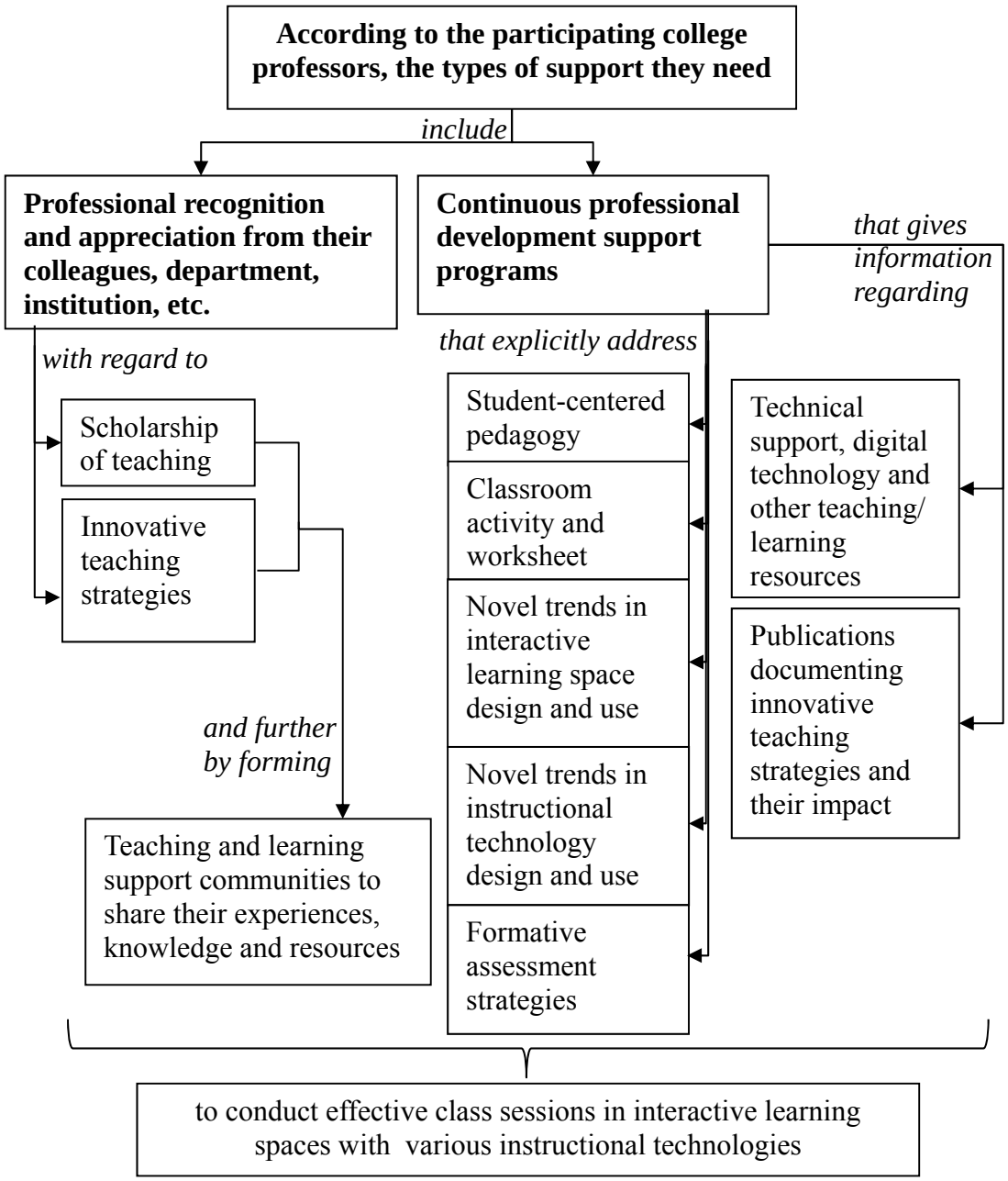

Figure 4-19: A schematic representation of college professors' desired support to be successful in utilizing instructional technologies and interactive learning spaces.

One of the most important factors was the amount of experiences these participants had teaching in a TILE classroom setting.

For example, Dr. Davis and Dr. Smith had the most TILE teaching experiences (3 and 4 semesters respectively). This information was obtained from completed questionnaires for Dr. Davis (questionnaire received on 05/21/2014) and Dr. Smith (questionnaire received on 03/13/2014). Both of them seemed to depend and draw largely from their previous TILE experiences. Both of them displayed a greater degree of confidence in designing activities and using various instructional technologies to manage a TILE class session effectively. Dr. Davis's and Dr. Smith's interview excerpts, found in sections 4.1.3.1E, 4.2.1 and 4.2, support these claims. Furthermore, both of these participants displayed an elevated awareness regarding student-learning pedagogy and related instructional strategies along with an increased awareness of education research literature related terminology and resources. Dr. Davis's interview excerpt concerning workshops she has attended (section 4.3.3.1B) and Dr. Smith's interview excerpt concerning the articles he has read (section 4.3.3.1G) support this claim. Moreover, both college professors mentioned how they had shared experiences with other professors who use similar instructional strategies, especially in the case of Dr. Davis, she mentioned how she is working to promote scholarship of teaching by giving formal presentations and talks regarding her teaching experiences in the TILE setting.

> *I was giving a talk on Friday for these group of (names a department in the institution) faculty and I was telling them that you can do version of these things (active-learning strategies) even in a classroom of three hundred people sitting in lecture rows, so you just have to be creative*
> (Interview with Dr. Davis, 05/21/2014)

Although it was her first semester teaching in the TILE classroom, Dr. Baker also displayed an elevated awareness of student-learning pedagogy thereby exhibiting confidence in designing activities and using various instructional technologies in the

TILE classroom setting. She attributed her confidence mainly to her own experience as a student from a small liberal arts college with an active-learning setting.

> *(So I'd say that I'm equipped to teach in the TILE room mainly because I did my undergraduate work at a small liberal arts college where active learning was a huge deal and so we didn't sit through a lot of lectures we did a lot more group activities.*
> (Interview with Dr. Baker, 05/23/2014)

She further mentioned that getting to know and working with other college professors who use innovative instructional strategies in their classrooms informed her about education research literature related terminology and resources

> *I have been talking to (names a colleague in the department) a lot because instead of using clickers they (students) use their smart phones and it is great because you can draw arrows, it come up on their smart phone drawing an arrow and showing which way the reaction go. I'd say she has sort of pioneered them for the classes previously and I'd like to try them in the Fall for the large course as well so we can bring a little bit more technology into the classroom.*
> (Interview with Dr. Baker, 05/23/2014)

Dr. Johnson who was teaching in the TILE classroom for the first time displayed slightly less familiarity with the student-centered paradigm and related instructional strategies when compared to the other college professors. His case expressed some unique situations and provided examples as to how he is gaining confidence in designing activities and increasing his awareness about novel instructional technology and interactive learning designs. For instance, he has a vast amount of experience teaching in the university and has seen advancements in digital technology over a long period of time (16 years). This information was obtained from completed questionnaires for Dr. Johnson (questionnaire received on 03/25/2014). Therefore he is using his experiences overtime particularly in digital technologies to better inform his teaching practices.

> *I could tell how much the students comprehended over and above once I incorporated PowerPoints way back when over pre-PowerPoint kinds of information so I thought this (teaching in TILE) would probably be that kind of leap forward as well.*
> (Interview with Dr. Johnson, 05/23/2014)

Dr. Johnson also stated how he gathered a lot of experiences watching other faculty members teach in the TILE setting and getting suggestions from faculty members how has more experiences in TILE setting.

> *To be honest in that regard (writing and conducting activities), I felt more comfortable in being led by (primary instructor of the course) or how other instructors did it. I sort of took their lead for that so I would often write up and suggest the activity and then they (team-teaching members) would say then why don't we do it this way and I would see the logic in it and go with the plan. …in Monday planning sessions what some of the other TAs and other faculty members suggested, I found those to be particularly useful.*
> (Interview with Dr. Johnson, 05/23/2014)

Dr. Johnson highlighted two important points during his interview. One was how senior college professors seem to be missing the opportunities to keep up with the novel trends in undergraduate education.

> *I think it is easy sometimes for more senior professors to perhaps lose sight of where things are happening.* (Interview with Dr. Johnson, 05/23/2014)

The other point was how discipline based educational research can assist college professors in their teaching endeavors.

> *I suspect what has happened is that there haven't being enough instructors out there in our field doing exactly this kind of thing (teaching with innovative technologies and strategies) and these kind of classrooms (TILE) to then produce the kinds of web based simulations exercises that we can then use.*
> (Interview with Dr. Johnson, 05/23/2014)

Overall, the most influential factors that enabled these college professors to be successful in terms of using instructional technologies and interactive learning features were found to be (1) the direct exposure to such technologies and learning spaces (i.e. teaching in TILE settings), (2) familiarity with student-centered pedagogy and related

instructional strategies via (a) professional development workshops, (b) exchanging ideas with other faculty members who are also engaged in novel instructional strategies, (3) educational research literature in general, and (4) discipline based education literature.

CHAPTER 5

DISCUSSION

Chapter 5 presents the conclusions and main discussion points emerging from this study. Section 5.2 briefly summarizes the main findings and states the conclusions while reiterating the purpose of this research study. Following that, section 5.3 presents three major discussion points in detail. Sections 5.4 and 5.5 respectively discuss the implications and future directions of this study. Section 5.6 concludes the chapter with the strengths and limitations of this study.

5.1 Main findings and conclusions

5.1.1 Research purpose

The purpose of this research study was: 1) to explore college professors' perception of instructional technology and interactive learning space use, and 2) to examine the extent to which their instructional decisions and practices are affected by teaching in technology-infused interactive learning environments. Further, this research study aims to use the findings and insights gained through the four case studies to better inform the enactment of effective professional development workshops and support programs for college professors.

5.1.2 Brief summary of main findings

All four of the participating college professors employed a variety of instructional technologies and learning space features to actively engage their students in classroom activities (e.g., mini-lectures, small group work, whole class discussions etc.). Similarities and differences were observed in terms of the types of digital/non-digital technologies, instructional strategies, and learning space features used by these four faculty members. Overall, the college professors' decisions to use a given instructional strategy or a technology were based on their view of learner-centeredness. These college professors' desire to promote student engagement with course materials while encouraging student-student, student-instructor discourse was a primary focus. However,

instructor-centered aspects such as attaining self-satisfaction and efficacy by encouraging themselves to participate in novel and effective instructional strategies was also found to significantly impact their decision making processes.

The influence of instructional technologies and interactive learning space features was most prominently seen at the lesson planning and lesson execution stages. In contrast, this influence was found to be the least prominent at the student assessment stage indicating college professors' insufficient awareness of on-going formative assessment strategies that align with student-centered pedagogy.

All four of the participating college professors perceived the instructional technologies and learning space features to be greatly beneficial in terms of enabling them to engage in an assortment of classroom activities to elevate student learning. The challenges mentioned by all participating college professors primarily concerned the danger of hindering student learning. Consequently, these challenges revolved around the difficulty of deciding useful instructional strategies and designing effective classroom activities thus revealing college professors' inadequate knowledge of student-centered pedagogy and assessment practices. Mirroring these challenges, all participating college professors indicated that they were in need of additional professional development, support, and resources to develop more effective classroom activities that lead to elevated student learning gains. Furthermore, college professors revealed the value of being recognized by their colleagues and departments for their involvement in scholarship of teaching.

5.1.3 Conclusions

With regard to the results and findings obtained for each research question, the following major conclusions are made.

In response to RQ1:

All the participating college professors of this study employed a variety of instructional technologies and learning space features to actively engage their students in

classroom activities. They employed team-based learning strategies, inquiry-guided learning strategies, and hands-on learning strategies regularly in their class sessions. Thus, these college professors' pedagogical reasoning behind their instructional decisions and practices were mainly based on promoting student engagement, encouraging student-student and student-instructor discourse, and generating successful student learning experiences.

In response to RQ2:

Participants were largely influenced by the instructional technology and the learning space features at the lesson planning and execution stages, whereas the influence was less notable at the student assessment stage. These college professors' used the variety of digital technological features (student laptops, LED screens, work station etc.), and learning space features (round tables, whiteboards etc.) offered in the TILE classroom to creatively design lessons and classroom activities for the students.

In response to RQ3:

These college professors perceived technology-infused interactive learning environments to be advantageous in-terms of enabling flexibility and creativity along with easy facilitation of classroom activities. However, they felt challenged when designing effective classroom activities and preferred continuous professional development support that explicitly addressed student-centered pedagogy, inquire-guided activity development, team-based activity development, and management of healthy group dynamics.

Taken altogether, the results and findings obtained from this study lead to the following overarching conclusions.

Overarching conclusions:

(1) Participating college professors' perceived benefits and challenges of instructional technologies and interactive learning space features closely mirrored their pedagogical reasoning behind choosing a particular instructional technology or a learning space

features. Therefore the relationship between benefits/pedagogical reasoning and challenges represented the two sides of a coin. For example, the learner-centered aspects of their pedagogical reasoning and benefits (i.e. promoting student engagement and learning gains with optimally using the available technological and learning space features) can be considered one side of the coin and the learner-centered aspects of their challenges (i.e. impeding student engagement and learning gains with misusing the available technological and learning space tools) can be considered the flipped side of the coin.

(2) Findings of this study also indicated a misalignment between all four college professors' knowledge bases regarding lesson-planning, lesson-execution, and student assessment. However, the extent of this misalignment seemed to vary from one participant to another depending on their exposure to innovative instructional strategies, education research literature, and previous teaching experiences.

(3) This study further revealed these four college professors' struggle between self-centered benefits and reasoning (such as self-satisfaction and self-efficacy gained through participating in innovative instructional strategies) and recognition-centered challenges (not receiving the deserved appreciation and support from their colleagues and departments) they are encountering in their professional careers.

These overarching conclusions are further discussed in subsequent sections.

5.2 Major discussion points

5.2.1 College professors' pedagogical decisions, perceived benefits and challenges revolve around the learners and learning process

As evident from the findings of this study, learner-centered factors (such as encouraging student-student/student-instructor discourse, promoting student engagement with the materials, providing hands-on learning opportunities for students, and enabling easy access to class materials and learning resources for students etc.) were the primary

focus of all four participating college professors' decision-making processes regardless of their disciplinary expertise and course demographics (introductory vs. advanced, major vs. non-major etc.). This learner-centeredness of their decision-making processes was further mirrored when they explained the benefits they encountered while teaching in technology-infused interactive learning environments. Moreover, the challenges and difficulties these college professors faced while teaching in technology-infused interactive learning environments also paralleled their learner-centered decision-making processes. Therefore, it can be concluded that these four college professors' decision-making processes, benefits and challenges are interrelated and interwoven. This interrelatedness reflects these college professors' knowledge of learner-centered paradigms and their desire to promote learners' knowledge construction. Such awareness concerning the learners and learning process is of vital importance simply because the progression towards a leaner-centered paradigm is at the center of higher education reform movements (Brown & Lippincott, 2003; Gaffney et al., 2008; Georgiana & Olson, 2008; Handelsman et al., 2004; Henderson et al., 2011; Oblinger, 2005; Park & Choi, 2014; Robertson, 2005). Therefore, the opportunities provided by trends in novel instructional technologies and learning space designs seemed to play an important role in assisting these college professors' transition from a teacher-centered pedagogy to a student-centered pedagogy.

The education literature reveals that higher education institutions, in which faculty members created an environment that emphasized active learning strategies and effective educational practices led to greater gains in undergraduate students' learning experience (Bonwell & Sutherland, 1996; Chen et al., 2008; Faust & Paulson, 1998; Umbach & Wawrzynski, 2005). In a similar qualitative research study, participating college professors stated that technology-infused interactive classrooms enabled them to facilitate collaborative learning and the use of pedagogies that were not possible in traditional classroom environments (Van Horne et al., 2014). In relation to these findings,

conclusions drawn from the current study further strengthen the need to encourage faculty members to adopt active learning strategies in their undergraduate classrooms. Furthermore, current study findings also illustrates the use of instructional technologies and interactive learning strategies as means to accomplish a variety of active learning strategies in undergraduate courses across disciplines. More importantly, current study findings about college professors' pedagogical reasoning, perceived benefits, and challenges of innovative instructional strategies inform the numerous stakeholders of the higher education system (educators, education researchers, administrators, policy makers etc.) and influence the higher education reform movement.

As mentioned above, these faculty members' perceptions of instructional technologies and interactive learning spaces also included certain challenges and difficulties. In a previous study, college professors indicated their concerns regarding how some activities might not be suitable for the course content and learners in their classroom, thus reducing the effectiveness of the learning process (Van Horne et al., 2014). Several research studies reported that college professors often struggle with dividing and balancing their time between teaching activities (designing effective lesson plans that include innovative learning strategies, classroom activities, and worksheets etc.) and research activities. This struggle was particularly prominent among the faculty members of research intensive (R1) universities (Brown et al, 2004; Felder & Brent, 1996; Beggs, 2000; Groves & Zemel, 1999; Spotts & Bowman, 1995; Van Horne et al., 2014). This is an interesting finding simply because the four participants in the current study expressed varying levels of concerns with respect to the time they are allocating to design classroom activities. Dr. Davis and Dr. Smith expressed the least concern with respect to time allocations, which can likely be attributed to the increased amount of experience and practice they have gained teaching in a TILE classroom (Dr. Davis and Dr. Smith had more than three semesters of TILE teaching experiences). Further, Dr. Smith and Dr. Davis exhibited an increased awareness about science education literature and had

experiences participating in professional development workshops. Dr. Baker' TILE teaching experiences was not extensive. Yet her experiences as a graduate student in a small liberal arts college with an active learning culture aided her in classroom activity design. Thus she did not consider 'time' to be an issue. However, Dr. Johnson, who did not have any experiences in TILE teaching and only had a limited understanding of active learning pedagogy, expressed the greatest concern with respect to time allocations to design classroom activities. All four participants indicated their concerns about the breadth/depth of the classroom activities and worksheets they have designed for their students. These concerns included the quality and richness of the learning experiences, the level of difficulty and challenge of the learning experiences, the alignment of the learning goals with the learning experiences, and the flow of the learning experiences with other topics, subtopics and the big picture. Therefore, the amount of experience a faculty members has in terms of educating themselves about student-centered pedagogy, the education literature, as well as first-hand involvement of designing classroom activities may take advantage of their enhanced knowledge bases to overcome 'time' and 'content' issues.

In addition to expanding their pedagogical knowledge base with gaining first-hand experiences in student-centered pedagogy and related activity design, college professors also need to familiarize themselves with the developments in instructional technology and learning space design. The following trends seemed to emerge while looking through the literature relevant to technological and learning space advancements over the past few decades. Firstly, faculty perceived benefits of instructional technologies have become increasingly student-centered (Beggs, 2000; Bennett & Bennett, 2003; Bonwell & Sutherland, 1996; Brown et al., 2004; Faust & Paulsen, 1998; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Groves & Zemel, 1999; Hooper & Rieber, 1995; Major & Palmer, 2006; Miller et al., 2000; Roberts et al., 2007; Spotts & Bowman, 1995; Umbach & Wawrzynski, 2005; Van Horne et al., 2014).

For example earlier studied documented how instructional technologies were helpful to improve student learning, student interest, and accessibility. These studies have also documented how faculty members' attitudes and beliefs dominated the use of instructional technologies in undergraduate classrooms (Beggs, 2000; Bonwell & Sutherland, 1996; Faust & Paulsen, 1998; Groves & Zemel, 1999; Hooper & Rieber, 1995; Miller et al., 2000; Roberts et al., 2007; Spotts & Bowman, 1995). Over time, with the expanding popularity of student-centered instructional paradigms, faculty members' exposure to student-centered instructional strategies and instructional technologies have made faculty perceived benefits of instructional technologies progressively student-centered (Bennett & Bennett, 2003; Brown & Lipincott, 2003; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Handelsman et al., 2004; Henderson et al., 2011; Major & Palmer, 2006; Miller et al., 2000; Park & Choi, 2014; Roberts et al., 2007; Umbach & Wawrzynski, 2005; Van Horne et al., 2014).

Despite these movements, several challenges and difficulties of adopting innovative instructional strategies and technologies have remained rather same. These include both individual and institutional barriers (Beggs, 2000; Bennett & Bennett, 2003; Bonwell & Sutherland, 1996; Brown et al., 2004; Faust & Paulsen, 1998; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Groves & Zemel, 1999; Hooper & Rieber, 1995; Major & Palmer, 2006; Miller et al., 2000; Roberts et al., 2007; Spotts and Bowman, 1995; Umbach & Wawrzynski, 2005; Van Horne et al., 2014). For example, inconsistent professional development support concerning student-centered pedagogy and classroom activity design (e.g., designing learning objectives, learning experiences and assessment strategies, small group activities, resolving small group dynamics, using clickers or other student response systems etc.) are documented as a persistent challenges in research literature (Bennett & Bennett, 2003; Faust & Paulsen, 1998; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Roberts et al., 2007; Umbach & Wawrzynski, 2005; Van Horne, 2014). Furthermore,

finding effective technological resources (e.g., gaining access to web-based resources, software programs etc.) and troubleshooting support also seemed to be persistent challenges according to the literature (Bonwell & Sutherland, 1996; Brown et al., 2004; Faust & Paulsen, 1998; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Groves & Zemel, 1999; Hooper & Rieber, 1995; Major & Palmer, 2006; Miller et al., 2000; Roberts et al., 2007; Umbach & Wawrzynski, 2005). Lack of technological literacy and lack of awareness of advancements in educational literature were also found to be challenging (Bennett & Bennett, 2003; Brown et al., 2004; Faust & Paulsen, 1998; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Roberts et al., 2007; Umbach & Wawrzynski, 2005). These documented findings are further strengthened by the findings of the current study. Therefore, one of the main implications of the present study is to provide confirming evidence to educators, education researchers, administrators, and policy makers to devise efficient and methodical measures to resolve these challenges and difficulties while reinforcing the implications of the existing studies. These efficient and methodical measures need to address effective dissemination of innovative instructional strategies, consistent implementation of professional development programs to provide hands-on experiences to improve faculty members' technological literacy and pedagogical knowledge (Beggs, 2000; Bennett & Bennett, 2003; Bonwell & Sutherland, 1996; Brown et al., 2004; Faust & Paulsen, 1998; Felder & Brent, 2004; Georgiana & Olson, 2008; Grasha & Yangarber-Hick, 2000; Groves & Zemel, 1999; Hooper & Rieber, 1995; Major & Palmer, 2006; Miller et al., 2000; Roberts et al., 2007; Spotts & Bowman, 1995; Umbach & Wawrzynski, 2005). Furthermore, higher education institutions need to devise faculty mentoring groups, faculty incentives and supportive infrastructure consisting of institutional leaders, administrators and faculty members to address necessary changes to their teaching and learning culture as a whole (Bennett & Bennett, 2003; Brown &

Lippincott, 2003; Brown et al., 2004; Chen et al., 2008; Georgiana & Hosford, 2009; Miller et al., 2000; Umbach & Wawrzynski, 2005; Van Horne et al., 2014).

5.2.2. College professors' exhibit a lack of alignment across lesson planning, execution, and student assessment

Black and William (1998) define assessment broadly to include all activities that teachers and students undertake to get information that can be used diagnostically to alter teaching and learning. Under this definition, assessment encompasses teacher observation, classroom discussion, and analysis of student work such as homework and tests. These assessment strategies become formative when they are used to modify and adjust existing instructional strategies to meet student needs. Formative assessment is tightly linked with daily instructional practices. Therefore, instructors need to consider how their classroom activities and assignments support the learning goals and allow students to communicate what they know, while accommodating this information to improve their teaching and learning strategies (Boston, 2002). Furthermore, formative assessment was also found to increase students' long-term retention of studied materials (Black & William, 2003). Moreover, formative assessment strategies can be used to provide useful feedback to students (Boston, 2002; Black & William, 2003). Several research studies over the years have found misalignments between instructors' (both college professors and K-12 teachers) conceptions concerning their pedagogy and claimed educational practices, particularly their student assessment practices (Henderson et al. 2011; Murray and Macdonald, 1997; Petcovic et al., 2013; Salder, 1989; Steadman, 1998). These studies found out that instructors often express attitudes and beliefs about their teaching that are not translated into their teaching strategies and methods. These studies also reported that instructors have inconsistencies concerning the purposes of lecturing, doing tutorials, and conducting assessment. Instructors often viewed themselves as facilitators, or student supporters, who inform knowledge, motivate students, and facilitate student learning. However, assessing students' knowledge seemed to conflict with this 'facilitator view'

(Henderson et al. 2011; Murray and Macdonald, 1997; Petcovic et al., 2013; Robertson, 2005).

In this study, evidence emerged from both classroom observations and interviews to support the notion that these college professors viewed student assessment to be a separate activity from their lesson planning and execution activities. These participants always viewed student assessment to be traditional and summative. In other words, student assessment was viewed as an end product to evaluate their students' learning rather than an on-going process to assess students' comprehension of the subject matter within a given class session/lesson execution. All four participants engaged in various activities (clicker questions, reporting out answers to classroom worksheets, small group and whole class discussions etc.) that had the potential to be used as formative assessment strategies. Yet, they didn't use the above mentioned activities as means of formatively assessing their students learning. However, it was also evident that the degree of misalignment between lesson planning/execution and student assessment was different from one participant to another. This could be due to their varying experiences in the TILE classroom setting and varying familiarity with student-centered instructional strategies and related assessment techniques. For example, Dr. Davis and Dr. Smith mentioned about how the activities themselves provide them with information as to how their students comprehend the subject matter. Both these participants have the most experiences in teaching in TILE classroom settings when compared to other participants. Yet they seemed to lack a firm awareness concerning the purposes and applications of formative assessment strategies. This lack of alignment between lesson planning, lesson execution, and student assessment may simply be due to their lack of awareness of the terminology used in the educational literature. It could also be due to lack of professional development support specifically addressing formative assessment strategies that are aligned with active learning pedagogy. Therefore, one of the main implications of this study is to inform professional development personnel regarding the design of workshops

to explicitly address formative assessment strategies that are aligned with student-centered pedagogy. Such programs can help college professors resolve their misalignment between conceptions of pedagogy and student assessment. Several researchers have also suggested the importance of designing effective professional development programs that specifically address both formative and summative classroom assessment strategies that are grounded in educational research literature (Black & William, 2003; Hubba & Freed, 2000; Murray and Macdonald, 1997; Petcovic et al., 2013; Robertson, 2005; Steadman, 1998). Additional implications include, incorporating subject specificity into these assessment workshops, forming faculty groups to reflect and share student assessment experiences, and developing institutional/departmental measures to devise systematic and productive student assessment programs. These implications are built on the suggestions from the existing literature (Black & William, 2003; Hubba & Freed, 2000; Murray and Macdonald, 1997; Petcovic et al., 2013; Robertson, 2005; Steadman, 1998).

5.2.3. College professors need department-/institution-wide systematic and sustained professional development support to enhance their contribution to the scholarship of teaching and learning

As evident from the results, these college professors invested time to prepare for their class sessions, design activities etc. Therefore, they felt accomplished and pleased when their students displayed increased engagement with subject matter, demonstrated better understanding of the materials, and achieved greater learning gains. In particular, in the case of the four participants of this study, seeing the fruitfulness of engaging in novel instructional strategies and technologies provided them with self-satisfaction, thus leading to self-efficacy.

However, the findings of this study also revealed that the four participating college professors perceived the lack of recognition and appreciation from their colleagues and departments to be challenging. The self-efficacy college professors

attained *via* their teaching accomplishments and the difficulty to overcome the under-appreciation for their contributions to improve scholarship of teaching and learning seemed to work against each other. This struggle seemed to negatively impact college professors' involvement in innovative instructional strategies. Several educational research studies and educational review literature have revealed similar findings. For example, while reviewing 191 conceptual and empirical journal articles (from 1995 to 2008) about current scholarship on how to promote change in instructional practices used in undergraduate STEM courses, Henderson et al. (2011) found that the nature of change strategies are weak and the research communities that study and enact changes are largely isolated from one another. The authors pointed out that this is mainly due to inconsistencies with respect to the change strategies responsible for disseminating curriculum and pedagogy, developing reflective teachers, enacting policy, and developing shared vision. Similarly, Handelsman et al., (2004) stated that research universities should provide leadership in the reform movement by promoting faculty and administrator collaborations to overcome the barriers and to create an educational ethos that aids changes. Further, several studies indicated that universities should place greater emphasis on awareness of new teaching methods, provide incentives, perhaps allocate a portion of research startup packages to support participation at education workshops and meetings (Bennett & Bennett, 2003; Chen et al., 2008;Handelsman et al., 2004; Henderson et al., 2011; Hubba & Freed, 2000; Oblinger, 2005; Paulsen & Feldman, 2002; Schnieder and Shoenberg, 1999; Umbach & Wawrzynski, 2005; Van Horne et al., 2014). Several studies also recommended that universities need to provide venues for experienced instructors to share best practices and effective teaching strategies by forming educational faculty mentoring and support groups within their departments (Bennett & Bennett, 2003; Chen et al., 2008; Handelsman et al., 2004; Henderson et al., 2011; Hubba & Freed, 2000; Oblinger, 2005; Paulsen & Feldman, 2002; Schnieder and Shoenberg, 1999; Umbach & Wawrzynski, 2005). They further suggested the

administration needs to inform faculty members about education research literature and the instructional resources available to them so that they can make informed choices. These suggestions also included hiring tenure-track faculty members who specialize in discipline based education research and practice (Bennett & Bennett, 2003; Chen et al., 2008; Handelsman et al., 2004; Henderson et al., 2011; Paulsen & Feldman, 2002; Schnieder and Shoenberg, 1999; Umbach & Wawrzynski, 2005). Additionally, the reward systems such as tenure, sabbaticals, and awards need to be aligned with educational reform and changes envisioned. Moreover they suggested that education researchers engaged in education reforms should exhort faculty, staff, and administrators to dismiss the notion that excellence in teaching is incompatible with first-rate research (Bennett & Bennett, 2003; Chen et al., 2008; Handelsman et al., 2004; Henderson et al., 2011; Oblinger, 2005; Paulsen & Feldman, 2002; Schnieder and Shoenberg, 1999; Umbach & Wawrzynski, 2005). Some studies also suggested how faculty responsibility need not be limited to classroom teaching but also needs to extend to administrative and decision making processes that reinforce the identification and evaluation of successful instructional methods and assessment tools. Paulsen and Feldman, (2002), in their review of education literature regarding curricula reform, stated that sponsoring scholarly teaching, scholarship of pedagogical content knowledge, scholarly preparation and evaluation of college teachers not only promote but also maintain the quality in undergraduate education for future generations. Therefore, one other important implication of the present study is to provide strong evidence to better inform higher education institutions about their undergraduate education reform and instructional practices concerning their teaching and learning culture. Implications drawn from the current study closely map the existing studies thereby further reinforcing the importance of instructional change and reform in post-secondary institutions. Such change strategies need to be systematic, consistent and long-term interventions that are aligned with the beliefs of the individuals involved (faculty and administrators alike) and require an

understanding of the institution thereby designing a strategy that is compatible with the entire system (Bennett & Bennett, 2003; Chen et al., 2008; Handelsman et al., 2004; Henderson et al., 2011; Hubba & Freed, 2000; Oblinger, 2005; Paulsen & Feldman, 2002; Schnieder and Shoenberg, 1999; Umbach & Wawrzynski, 2005; Van Horne et al., 2014).

5.3. Implications for post-secondary education

As discussed under the three major discussion points above, the current study provides several major implications concerning the enhancement of the undergraduate education experience. These implications add to the education research literature while reinforcing some of the existing suggestions.

(1) Higher education institutions (departmental and/or institutional level) need to implement effective continuing professional development programs for their faculty members that explicitly address:
    a. learner-centered pedagogy and related classroom activity design
    b. small group dynamics and related instructional strategies
    c. research findings concerning innovative teaching strategies and practices
    d. research findings concerning trends in novel learning space designs and instructional technologies
    e. ways to find pedagogical and digital/non-digital educational support and resources
    f. the use of formative assessment strategies in classrooms
    g. discipline specific education research and its consequences

(2) Higher education institutions (departmental and/or institutional level) need to conceive effective educational reform movements that are acknowledged at all levels of the organizational structure. These organizational- and/or departmental-wide actions may include:

a. the formation of teaching and learning communities (or a teaching culture) that support the dissemination of effective instructional practices and resources
b. the establishment of incentives that enable college professors' participation in various professional development programs, workshops, conferences etc. that specifically focus on teaching.
c. the development of incentives that recognize college professors' contribution to the scholarship of teaching and learning and include them in tenure and promotion decisions

5.4. Directions for future research

This study was conducted as an exploratory study that included only four college professors from a given university encompassing only one semester of data collection. Therefore the potential exists to expand this study in multiple directions. Firstly expanding the case studies to include more participants representing different institutions (small four year colleges, research universities etc.), different disciplines (in STEM, liberal arts etc.) and longer data collection periods can provide a comprehensive understanding of college professors perception of instructional technology and interactive learning environments. Further, a longitudinal aspect in data collection may be of importance to explore how college professors' perceptions change over time depending on extended exposure or differential exposure to instructional technologies and interactive learning space features. Such a modification may also be influenced by their conduction of different courses in different semesters. Moreover, conducting pre- and immediate post-classroom observation interviews can be more informative in terms of gathering data regarding their pedagogical reasoning and decision-making processes. The potential also exists to design similar studies to investigate how graduate teaching assistants (GTA) perceive instructional technologies and interactive learning spaces while engaging in their teaching responsibilities. Such an investigation can provide insight into

developing effective GTA development programs as well as an early glimpse into the transition from GTAs to prospective faculty members. Findings of such a study can reveal the factors that may influence or impede the sustainability of learner-centered paradigms and innovative instructional practices in prospective faculty members. Furthermore, GTAs' perceptions of discipline specific education research and educational research in general can offer insights into how prospective faculty members make informed decisions regarding their forthcoming professional careers.

Although it was not an explicitly addressed research question in this study, some evidence emerged to suggest the likelihood of sustained innovative teaching practices among the four participants. These sustained innovative teaching practices refers to the teaching practices the four participants developed while teaching in technology-infused interactive learning environments and evidently transferred to other learning environments (i.e. conducting small group work, class discussions, or using digital/non-digital instructional tools in their courses that are conducted in traditional learning environments). However, the degree of sustainability of their teaching practice seemed to vary from one participant to another. This may depend on their previous teaching experiences, exposure to learner-centered pedagogy, education research literature and certain professional development programs. Therefore, investigating the degree to which innovative instructional practices enacted in the technology-infused learning spaces are carried on to other learning environments (such as traditional lecture rooms) along with the factors that influence or impede this transfer process is an important future research direction.

Another potential point of interest that emerged from this study was the distinction college professors made between digital technologies (e.g. work station, laptops), non-digital technologies (e.g. whiteboard and markers) and learning space features (e.g. round tables) that were found in the TILE classroom. This study did not intend to distinguish between technological (digital and/or non-digital) affordances, and

learning space affordances thus the research questions did not treat the above aspects separately. Based on the insights gained through this study, formulating future research questions that separately address college professors' perception of innovative instructional strategies with respect to technological and learning space affordances can provide in-depth information regarding their instructional decisions and practices.

5.5. Strengths and limitations of this study

5.5.1. Strengths

This research study used a multiple-case study of four college professors from a large public Midwestern university who conducted their undergraduate science classes in a technology-infused interactive learning space known as a TILE classroom. These four participants represented four different departments in the university and had expertise in four different academic disciplines. Further, these four participants had teaching experiences ranging from four years to more than ten years, and they represented academic ranks from assistant professor to associate professor to professor. Moreover, participating college professors represented both genders and had varying experiences in conducting classes in the TILE classroom (first-time TILE teaching to four times TILE teaching). Therefore, I believe the amount of variation captured through the four cases added an ample richness to the results and findings, hence enhanced the implications drawn from this study. Furthermore, each participant was observed at three randomly chosen class sessions (except for Dr. Johnson who only had two class observations). Multiple observations such as these increase the reliability of the findings *via* eliminating any lone or unique events that might have led to biased interpretations. Moreover, all four participants conducted their class sessions in the same TILE classroom. Therefore, the availability of IT resources and learning space features were kept constant throughout the study by employing the same classroom environment across the four participants.

Three data collection methods (questionnaires, classroom observations and semi-structured interviews) were utilized during this study. These three methods provided a

means to comprehensively capture the phenomena under study. For example, during the data analysis, transcripts generated from both classroom observations and interviews were used to formulate answers. This is termed methodological triangulation (Stake, 1995). Moreover, during the data analysis, transcripts generated from both classroom observations and interviews were used to formulate answers. Furthermore, I used the information gathered from participants' classroom observations and questionnaires to inform the semi-structured interviews. This is an example of data source triangulation (Stake, 1995). The idea behind such triangulation is to see whether the phenomenon under study stays the same for different situations and different interactions (for example, whether each participant's perception of interactive learning strategies stayed the same when he/she was conducting the class sessions as well as when he/she explained them to me during the interview). These triangulation strategies along with peer debriefing increased the credibility, dependability, and transferability of this study (Lincoln & Guba, 1985; Merriam, 2009).

5.5.2. Limitations

Despite the above mentioned strengths, there are also some limitations associated with this study. As mentioned above, this study included case studies of four college professors with versatile backgrounds and teaching experiences. All four college professors represented science disciplines therefore, their viewpoints and perceptions may not be a representative of those college professors who have expertise in disciplines such as liberal arts, businesses, nursing, engineering, social sciences etc. Furthermore, this study took place in one type of technology-infused learning environment within a large public university and that may also limit its applicability to other contexts such as different higher education institutions and interactive learning environments. Moreover, this study collected data for the duration of one semester, thereby including only one course taught by each participating college professor. This can be a limitation in the sense that college professors' instructional decisions and practices may be influenced by

teaching different courses (different content, different learners etc.) at different points of the academic year. Therefore, observing at least two courses (ideally in two different semesters) can provide a much more comprehensive result regarding college professors' pedagogical reasoning behind their choice of instructional strategies and instructional tools. Additionally, there were no classroom observations documenting these participants' instructional practices in traditional classroom settings. Any evidence of perceived benefits, challenges, and reasoning were obtained only through participant interviews. Use of traditional lecture-based classroom observations might have been a potential opportunity for data triangulation along with the interviews.

During this study, I observed up to three class sessions for each participating college professor and interviewed each participant once at the end of the semester (at the end of the course). Even though three random class sessions may provide a representative look at the general flow of the course and college professors' choice of instructional strategies and technology use, class sessions dynamics may be different from time to time (difficulty of the topic discussed, nearing an exam, nearing a vacation etc.) Such dynamics can introduce random occurrences that might have erroneously influenced this study.

Furthermore, I only interviewed at the end of the semester when the entire course had reached an end. Interviewing the participants at the end takes a retrospective approach having participants reflect on the benefits and challenges of their teaching decision. However, in the light of RQ1, conducting immediate post-classroom observation interviews might have revealed more information regarding their choice at that point of time, without having to reflect on them at a later date. Therefore, it might have increased the credibility of this study if I had conducted three short immediate post-classroom observation interviews in addition to the end of the semester interview with each study participant.

This study collectively investigated college professors' perceptions of instructional technologies and interactive learning spaces. This holistic nature might have concealed the unique aspects of instructional technologies and interactive learning spaces that could only be revealed upon an in-depth investigation of each topic (instructional technologies and interactive learning spaces as separate constructs) by itself.

A characteristic of all forms of qualitative research is that the researcher is the primary instrument for data collection and analysis. The main advantage of the 'human instrument' is the ability to be immediately responsive and adaptive, thus providing an ideal means of collecting and analyzing data. Other advantages include the ability of the researcher to expand his or her understanding through nonverbal and verbal communication, process information immediately, clarify and summarize material, check with respondents for accuracy of interpretation, and explore unusual or unanticipated responses (Merriam, 2009). However, the human instrument has shortcomings and biases that might have an impact on the study. The quality of self-awareness of the potential effects of self on your research is termed as 'subjectivity'. Qualitative researchers recognize that subjectivity is always a part of research from the deciding on research topic, data collection, analysis and interpretation. Subjectivity once recognized can be monitored for more trustworthy research and subjectivity in itself can contribute to the research, through reflexive thought. The researcher can probe even more into his/her subjectivities as part of the research setting, context and social phenomena under study (Glesne, 2006; Lincoln & Guba, 1985; Merriam, 2009).

APPENDIX A

Impact of Technology Infused Classrooms (TILE) on Instructor Decisions and Practices

Questionnaire protocol

Following questions will be utilized by the research team to gather project-relevant demographic information about the participant population.

Please mark your response/s with a √ mark.

1. My teaching experience as a faculty member is: (please include years of experiences before the University of Iowa if any)

☐	One to three years
☐	Three to five years
☐	Five to ten years
☐	More than ten years

Years of experiences before University of Iowa _____

2. I have experience in teaching in a TILE classrooms (or any equivalent technology infused classroom) setting for:

☐	Two to three semesters
☐	Three to five semesters
☐	More than five semesters
☐	This is my first semester teaching in a TILE setting

I have experience in teaching in _____ (name of the equivalent classroom setting) for _____ semesters.

----------Please continue to next page----------

3. Courses I conducted in a TILE classroom setting include students who are primarily: (mark all that apply)

- ☐ Freshmen
- ☐ Sophomores
- ☐ Juniors
- ☐ Seniors
- ☐ Majors of my discipline
- ☐ Majors out of my discipline
- ☐ Others (please specify)

4. Please indicate the types of equipments you have used/ are using in your TILE classroom

- ☐ Desktop PC and podium setting at the center
- ☐ Screens and/or LCD monitors
- ☐ Document camera (doc cam)
- ☐ DVD player
- ☐ Microphones for instructor
- ☐ Microphones on student tables
- ☐ Whiteboards
- ☐ Student laptops on round tables
- ☐ Other (please specify)

----------Please continue to next page----------

5. Please indicate the types of technologies you have used/ are using in your TILE classroom(mark all that apply)

- ☐ Microsoft office (powerpoint, word, excel etc.) or equivalent office software
- ☐ ICON or similar online course websites
- ☐ World Wide Web (can include websites, web-base simulations or tools, videos, blogs, scholarly article searches etc.)
- ☐ Subject specific software designs, mobile apps etc.
- ☐ Other (please specify)

6. How did you get to know about TILE classroom facilities in the University of Iowa? (mark all that apply)

- ☐ Center for teaching, UI
- ☐ Colleagues in the department
- ☐ Colleagues in other departments
- ☐ Students
- ☐ Other (please specify)

7. How did you obtain your training to teach in a TILE classroom setting? (mark all that apply)

- ☐ I participated in a TILE workshop conducted by the UI
- ☐ I observed colleagues/ other faculty members teaching in a TILE classroom setting
- ☐ I have not had any training regarding teaching in a TILE classroom setting
- ☐ Other (please specify)

----------Please continue to next page----------

8. Please provide the following information relevant to the course that the video-recordings are conducted

(A) Number of students enrolled (as of the beginning of the semester):

_____

(B) Composition:

_____
_____

(for example, *about 70% are freshmen students*, *all students are majors in my discipline* etc.)

(C) Have you taught this course before?

_____ YES _____ NO

(D) If YES,

I taught this course in a TILE classroom setting for _____ semesters.

I taught this course in a traditional classroom setting for _____ semesters.

(E) If NO,

Have you taught a similar course or similar materials in another course before?

_____ YES _____ NO

(F) Other information:

_____
_____

(For example, *this course provides general education requirement*, *this course is required for majors in my discipline* etc.)

APPENDIX B

Impact of Technology Infused Classrooms (TILE) on Instructor Decisions and Practices
Observation protocol

Classroom observation number:

Date:

Time:

Duration:

Place/location:

Participant pseudonym:

Course:

Topic of the day:

My place in the room:

Other details:

Teaching/ classroom activity	Duration of activity	Aspects of learning space features	Aspects of technologies (digital, non-digital)	Evidence-based teaching practices(what instructor/students is/are doing)	My comments/ thoughts/ interpretations

APPENDIX C

Impact of Technology Infused Classrooms (TILE) on Instructor Decisions and Practices
Interview protocol

Following questions will be used to guide the semi-structured interview with the subjects at the end of the semester to study more about their teaching experience in the TILE classroom setting

1. Why did you choose to teach in a TILE classroom? (What student learning outcomes (content/skills) did you expect to achieve for this course by using the TILE classroom setting)?

2. Were you able to achieve these learning goals for your course? Why or why not?

   Follow up: if yes, what aspects of the TILE classroom (technology and learning environment) helped you achieve these learning goals and how?
   If no, what aspects of TILE classroom (technology and learning environment) hindered you from achieving these learning goals and how

3. What benefits did you encounter while teaching in the TILE classroom setting?
   Please explain

4. What challenges did you face while teaching in the TILE classroom setting?
   Please explain

   Follow up: Do you think that you get enough technical support from the department IT staff/University IT staff regarding any technical issues you face in the TILE classroom? Please explain

5. How did your students respond to the instructional technology and learning environment in the TILE classroom? Did you notice any changes in their attitudes, level of engagement and achievement? Please explain
   Follow up: Have you conducted any formal/informal assessment to gather student feedback, comments, or suggestions regarding the course and TILE classroom?

6. How well do you think you are equipped to teach in a TILE classroom?

7. What are the areas that you expect to professional improve in order to teach in a TILE classroom? please explain
   Do you think that you are getting enough professional development support from your department/the university/center for teaching etc. regarding effective instruction in a TILE classroom? Please explain

8. Have you changed or modified any of your lesson plans or class-activities in order to accommodate the technology and learning environment in the TILE classroom? Can you give some examples?
   Follow up: Do you think the modification helped your students better understand the topic? Why or why not?

9. Are you thinking of changing or modifying any of your current lesson plans and class-activities in order to accommodate the technology and learning environment in the TILE classroom for future semesters?

   Follow up: are you thinking of utilizing any lesson plans and class-activities you developed for the TILE classroom in a traditional classroom setting? If so how?

10. What changes have you noticed (if any) about your teaching pedagogy, teaching philosophy, and teaching practices after the experience of TILE classroom teaching? Please explain

APPENDIX D

List of codes

Access to resources
Active learning for students
Admin issues in department
Administration personnel in PD
Addressing small group issues
Amenities in TILE
Assign/ share responsibilities
Big ideas
Blog
Breadth/depth in activity writing
Center for teaching help
Change in student learning
Choosing useful tech tools
Class debate
Classroom activities
Clickers
Confidence
Continuous tech support
Co-teaching member input
Course website
Creative
Daily activity assessment potential
Data driven PD
Day to day operation
Dedicated TILE support
Different versions of PD/targeted PD
Different learning tools-specimens, model kits etc.
Discussion within colleagues and departments
Doc-cam
Educational literature
Encourage small groups
Enthusiastic
Exam results
Faculty comfort with student-centered pedagogy
Faculty comfort with tech use
Faculty thinking TILE has no value
Finding new technologies
Firsthand experience in PD workshops
Flexible
Forming small groups
Frustration
Fun experience/ great experience
Group quiz
Growing faculty community
Hands-on learning (for students)
Help with problem solving
IF-AT forms
Improvising
Ineffective PD
Informal assessment
Input for tenure and promotion
Inquiry-guided learning activities
ITS help
Learning objectives/goals
Lecture capture
Mix things up in class
Models demonstrations
Move about in TILE room
Not lecturing in class
New technologies
Not getting bored
Online activity template
Online quiz
Own reflection
Paper-pencil based assessment
PD for assessment strategies
PD for writing activities
PD for faculty orientation
PD for student-centered philosophy
PD for tech use in TILE
PD workshop for SCALE UP rooms
PowerPoint slides
Present concepts

Previous course experiences
Previous TILE experiences
Proactive
Problem solving
Provide students feedback
Pushback from colleagues/department
Rapport with students
Real world data/real world experiences
Report out answers
Round tables
Screens and projectors
Small college grad experience
Small group work
Student comfort in technology use
Student discussion/dialogue
Student engagement
Student feedback/response
Student group presentation
Student laptops
Student Share information/ opinions
Student talk to each other
Student work in groups
Student-instructor dialogue
Students ask questions
Students talk with instructor/TA
Student-TA dialogue
TA prep
Technological issues/glitches
Teaching in traditional classes
Teaching load issues
Teaching vs research balance
Team-based learning
Team-teaching issue
Tenure/promotion issues
Time consumption,
Time management
Trial and error
Videos
Wikisite
Web searches
Web simulations
Whiteboards
Whole class discussion
Work station
Writing/setting learning objectives

List of categories and subcategories and codes

RQ	Related categories and subcategories	Codes involved
RQ1: Pedagogical reasoning	*(1)Increase student engagement:*	
	• Encourage student-student interaction	Round tables Student engagement Students talk to each other Students work in groups
	• Encourage student-instructor interaction	Help with problem solving Provide student feedback Report out answers Students ask questions Students talk with instructor/TA Whole class discussions
	• Use new technologies available to deliver materials and manage/facilitate class activities	Course website Doc-cam PowerPoint slides Present concepts Real world examples Screens and projectors Student laptops Videos Web searches Web simulations Whiteboards Wikisite Workstation
	• Getting to know students	Move about in TILE room Rapport with students
	• Fresh perspectives	Blog Class debate Lecture capture Models demonstrations Different learning tools-specimens, model kits etc. Mix things up in class Not getting bored
	• Reflections on previous teaching experiences	Previous teaching experiences Teaching in traditional classes

	(2) Self-satisfaction and self-efficacy:	
	• Flexibility/creativity	Creative Enthusiastic Flexible New technologies
	• Positive student responses and self-reflections	Student feedback/responses Change in student learning
RQ2: Influence of instructional technology and learning space features	*(1)Lesson planning stage:*	
	• Extensive planning	Amenities in TILE Big ideas Classroom activities Co-teaching member input Learning goals/objectives
	• Reflection on previous experiences	Own reflections Previous course experiences Previous TILE experiences
	(2)Lesson execution stage:	
	• Managing class time	Time management Improvising
	• Classroom operation	Assign/share responsibilities Day-to-day operation Proactive TA prep Tech issues/glitches
	(3)Student assessment stage:	
	• Summative and traditional techniques	Exam results Paper-pencil assessments
	• Lack of awareness of purposes and utilities of formative techniques	Clickers Group quiz Online quiz IF-AT forms Informal assessment Student group presentations Daily activity assessment potential

RQ3 Overall perception of instructional technology and learning space features	*(1)Benefits:*	
	• Increased student discourse	Active learning for students Problem solving Student discussion/dialogue Student-instructor dialogue Student-TA dialogue Team-based learning
	• Ability to be flexible and creative when conducting classes	Confidence Fun experience/great experiences Not lecturing in class
	• Efficient delivery, conduction, management of classroom activities and course materials	Hands-on learning Online activity template Small group work Student share/ report out opinions/answers
	(2) Challenges:	
	• Difficulty in designing effective classroom activities	Breadth/depth in activity writing Faculty comfort with student-centered pedagogy Ineffective PD Inquiry-guided learning activities Writing/setting learning objectives Time consumption Trial and error
	• Managing good small group dynamics	Addressing small group issues Forming small groups Encouraging small groups
	• Deciding optimum technological, learning space features and instructional strategy	Faculty comfort with tech use Student comfort in tech use Choosing useful tech tools
	• Lack of recognition and appreciation for what they do (Scholarship of teaching and learning and Innovative teaching strategies)	Admin issues in departments Faculty thinking TILE has no value Frustration Pushback from colleagues/

		department Teaching load issues Teaching vs research balance Team-teaching issues Tenure/promotion issues
	(3) Desired support:	
	1. Continuous professional development programs	
	• Student-centered pedagogy	PD for student-centered philosophy Small college grad experience
	• Classroom activity/ worksheet design	Center for teaching help Different versions of PD/targeted PD Firsthand experience in PD workshops PD for writing activities
	• Trends in interactive learning space design, instructional technology and strategies	PD for tech use in TILE PD workshops for SCALE-UP rooms Finding new technologies
	• Formative assessment strategies	PD for assessment strategies
	• Education research literature	Data driven PD Educational literature
	• Accessing technological and pedagogical resources	Access to resources Continuous tech support Dedicated TILE support ITS help
	2. Institutional measures to recognition scholarship of teaching	Administration personnel in PD Discussion within colleagues and departments Growing faculty community Input for tenure and promotion PD for faculty orientation

Interrater Reliability_Coding Scheme_KW

RQ2: How do technology-infused interactive learning environments influence college professors' instructional decisions and practices at following stages: lesson planning, lesson execution, and student assessment?

Lesson Planning

- Designing interactive activities
- Considerations on the time management
- Considerations on the transitioning of the activities

Lesson Execution

- Transitioning of the activities
- Involvement of students in the classroom
- Providing interactive learning environments

RQ3: What is college professors' perception of technology-infused interactive learning environments in terms of benefits, difficulties and desired support?

Benefits

- Students' active engagement
- Cooperative learning environment
- Exchange of ideas
- Increased interaction
    - Among students
    - Between students and the instructor
- Better physical environment

Difficulties

- Designing activities to promote communication
- Scarce resource available in planning lessons
- Having all students to engage; not just the vocal students
- Time commitment in designing the activities/lesson – a lot of work, time-consuming

Desired support

- Demonstration of a lesson/simulation - A good lesson model
- Support that includes hands-on experience/exposure to the environment
- Convincing evidence of the effectiveness of the technology-infused interactive learning environments
- Support at the community-level
    - Department
        - Available/accessible help/assistance on-request (during class)
    - Colleagues' support: empirical evidence

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To: Chamathca Priyanwada Kuda Malwathumullage

From: IRB-02 DHHS Registration # IRB00000100,
Univ of Iowa, DHHS Federalwide Assurance # FWA00003007

Re: Impact of Technology Infused Classrooms (TILE) towards the Development of Teacher Knowledge

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Approval Date: 03/05/14

Next IRB Approval Due Before: N/A

Type of Application:

☒ New Project
☐ Continuing Review
☐ Modification

Type of Application Review:

☐ Full Board:
Meeting Date:
☐ Expedited

☒ Exempt

Approved for Populations:

☐ Children
☐ Prisoners
☐ Pregnant Women, Fetuses, Neonates

Source of Support:

This approval has been electronically signed by IRB Chair:
Janet Karen Williams, PHD
03/05/14 0508

IRB Approval: IRB approval indicates that this project meets the regulatory requirements for the protection of human subjects. IRB approval does not absolve the principal investigator from complying with other institutional, collegiate, or departmental policies or procedures.

Agency Notification: If this is a New Project or Continuing Review application and the project is funded by an external government or non-profit agency, the original HHS 310 form, "Protection of Human Subjects Assurance Identification/IRB Certification/Declaration of Exemption," has been forwarded to the UI Division of Sponsored Programs, 100 Gilmore Hall, for appropriate action. You will receive a signed copy from Sponsored Programs.

Recruitment/Consent: Your IRB application has been approved for recruitment of subjects not to exceed the number indicated on your application form. If you are using written informed consent, the IRB-approved and stamped Informed Consent Document(s) are attached. Please make copies from the attached "masters" for subjects to sign when agreeing to participate. The original signed Informed Consent Document should be placed in your research files. A copy of the Informed Consent Document should be given to the subject. (A copy of the *signed* Informed Consent Document should be given to the subject if your Consent contains a HIPAA authorization section.) If hospital/clinic patients are being enrolled, a copy of the IRB approved Record of Consent form should be placed in the subject's electronic medical record.

Continuing Review: Federal regulations require that the IRB re-approve research projects at intervals appropriate to the degree of risk, but no less than once per year. This process is called "continuing review." Continuing review for non-exempt research is required to occur as long as the research remains active for long-term follow-up of research subjects, even when the research is permanently closed to enrollment of new subjects and all subjects have completed all research-related interventions and to occur when the remaining research activities are limited to collection of private identifiable information. Your project "expires" at 12:01 AM on the date indicated on the preceding page ("Next IRB Approval Due on or Before"). You must obtain your next IRB approval of this project on or before that expiration date. You are responsible for submitting a Continuing Review application in sufficient time for approval before the expiration date, however the HSO will send a reminder notice approximately 60 and 30 days prior to the expiration date.

Modifications: Any change in this research project or materials must be submitted on a Modification application to the IRB for prior review and approval, except when a change is necessary to eliminate apparent immediate hazards to subjects. The investigator is required to promptly notify the IRB of any changes made without IRB approval to eliminate apparent immediate hazards to subjects using the Modification/Update Form. Modifications requiring the prior review and approval of the IRB include but are not limited to: changing the protocol or study procedures, changing investigators or funding sources, changing the Informed Consent Document, increasing the anticipated total number of subjects from what was originally approved, or adding any new materials (e.g., letters to subjects, ads, questionnaires).

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Additional Information: Complete information regarding research involving human subjects at The University of Iowa is available in the "Investigator's Guide to Human Subjects Research." Research investigators are expected to comply with these policies and procedures, and to be familiar with the University's Federalwide Assurance, the Belmont Report, 45CFR46, and other applicable regulations prior to conducting the research. These documents and IRB application and related forms are available on the Human Subjects Office website or are available by calling 335-6564.

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APPROVED BY: IRB-02
IRB ID #: 201402800
APPROVAL DATE: 03/05/14
EXPIRATION DATE: N/A

We invite you to participate in a research study being conducted by investigators from The University of Iowa. The purpose of this study is to investigate how teachers develop their knowledge base in terms of integrating technology into their classrooms. The investigators are interested in studying teachers' ability to use different types of technologies available in technology infused classrooms (TILE) as well as how these available technologies affect their teaching behaviors and practices. The investigators are also interested in evaluating how teachers perceive technology use (technical tool vs. pedagogical tool) in their classrooms.

If you agree to participate in this study, we would like you to allow the researchers to observe your usual TILE classroom teaching activities and record the use of technology during the lessons. Researchers will visit your classroom maximum of three times (class periods) during the semester to conduct the observations. You will be notified (via email) in advance before each visit. Researchers will observe the classroom activities and will make notes of the types of technology used during these activities by you. The video-recording process will start with the starting of the lesson and will continue towards the end of the lesson. The camera will be placed at the back of the classroom to follow your actions and words for the entire duration of the lesson to document the types of technologies used and how they were used by you during the lesson. During these recordings, researcher will also take notes to document the types of technologies used and how they were used by you during the lesson. You will be asked to complete a brief questionnaire regarding your experience in teaching and experience in teaching with technology at the beginning of this study. You will also be asked to participate in a semi-structured interview to share your perceptions/opinions of technology use in classroom towards the end of the semester. You are free to skip any questions that you prefer not to answer. It will take approximately 20 minutes to complete the questionnaire and one hour to complete the semi structured interview. This interview will take place in your personal office space and will be audio- recorded.

Your personal information (name, etc.) will not be collected during the survey and your responses will not be possible to link to you. The video recordings will not be identified by name, and it will not be possible to link your responses to you or to the video. Audio recordings of your interview will not be identified by name, and will not be possible to link your responses to you or to the audio.

Taking part in this research study is completely voluntary. If you do not wish to participate in this study, please tell the researcher that you do not wish to participate at this time and return this sheet to the investigator.

If you have questions about the rights of research subjects, please contact the Human Subjects Office, 105 Hardin Library for the Health Sciences, 600 Newton Rd, The University of Iowa, Iowa City, IA 52242-1098, (319) 335-6564, or e-mail irb@uiowa.edu.

Thank you very much for your consideration of this research study.

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