BLENDED, ACTIVE, AND PERSISTENT: AN INVESTIGATIVE STUDY OF BLENDED LEARNING AFFORDANCES FOR ACTIVE LEARNING AND STUDENT PERSISTENCE

By

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To my mom and dad who bore me in life, caught me in the darkness, and helped me to laugh in the light. To my husband who unconditionally loves and truly warms my heart.

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LIST OF ABBREVIATIONS

ACS	American Chemical Society
ARCS	Attention-Relevance-Confidence-Satisfaction model
AL	active learning
ALC	active learning classroom
BL	blended learning
BL4AL	Blended Learning for Active Learning
CFA	Confirmatory Factor Analysis
CLES	Constructivist Learning Environment Survey
CNTLM	confidence—nontraditional learning methods
CTLM	confidence—traditional learning methods
DBER	discipline-based education research
FERPA	Family Educational Rights and Privacy Act
FTF	face-to-face
ICC	interclass correlation coefficient
IS	identification as a scientist
ISNTLM	identification as a scientist—nontraditional learning methods
ISTLM	identification as a scientist—traditional learning methods
LCTSR	Lawson Classroom Test of Scientific Reasoning
LMS	learning management system
MNTLM	motivation—nontraditional learning methods
MTLM	motivation—traditional learning methods
NSF	National Science Foundation
NSH	no specific how

OAS	Office of Academic Support
OIRBS	Online Instructor Role and Behavior Scale
PDF	portable document format
PORTAAL	Practical Observation Rubric To Assess Active Learning
SC	student confidence
SL	science learning
SLNTLM	science learning—nontraditional learning methods
SLTLM	science learning—traditional learning methods
SM	student motivation
STEM	science, technology, engineering, and mathematics

Abstract of Dissertation Presented to the Graduate School
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BLENDED, ACTIVE, AND PERSISTENT: AN INVESTIGATIVE STUDY OF BLENDED LEARNING AFFORDANCES FOR ACTIVE LEARNING AND STUDENT PERSISTENCE

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Within the last 10 years, higher education has seen the accelerated development of blended learning (BL), active learning (AL), and STEM education. The presented mixed methods study examined a proposed framework that BL affordances enable or constrain AL, as a representation of constructivist learning theory, and that the relationship between BL affordances and AL influences student persistence in introductory science courses. Graham’s (2006) definition of BL along the four dimensions of space, time, humanness, and fidelity was paired with Meyers and Jones’ (1993) framework for AL as the combination of basic elements to learning, teaching resources, and learning strategies. The BL-AL relationship was then examined along the lines of Graham, Frederick, Byars-Winston, Hunter, and Handelsman’s (2013) four dimensions of student persistence—student motivation, student confidence, science learning, and identification as a scientist.

The research design followed Yin’s (2014) recommendations for a multiple-case study, in which one introductory physics course and one introductory chemistry course were the units of analysis. Interviewed were two student volunteers from each of the following groups: high-, average-, and low-performing. Content analysis was conducted

for course documentations on the course website and the learning management system Canvas™. In-class and online observations were evaluated using Eddy, Converse, and Wenderoth's (2015) Practical Observation Rubric To Assess Active Learning (PORTAAL) examining student practice, logic development, accountability, and reduction of apprehension. The researcher developed a survey instrument, Blended Learning for Active Learning (BL4AL), capturing students’ perspectives concerning AL through traditional and nontraditional learning methods for their persistence in the sciences. Findings indicated students from all levels had varying views of BL affordances in comparison to the original intention of the instructors. Study Edge©, a third-party tutoring service, was discovered to be an integral component to the students’ experiences of BL for AL and student persistence. The regression model using BL4AL responses was found to be significant in the physics course ($F(8, 218) = 7.69$, $p < .01$, $f^2 = .28$) and in the chemistry course ($F(8, 293) = 6.84$, $p < .01$, $f^2 = .19$), and explained 19% of variance in the former and 13% of variance in the latter.

CHAPTER 1
INTRODUCTION

Context

As higher education continues to evolve, two prominent trends have emerged in 21st century higher education in the United States: the focus of funded support for Science, Technology, Engineering, and Mathematics (STEM) education and the increase of courses with blended learning (BL) designs. The National Science Foundation (NSF) alone supports about 24% of all federal funding for research among U.S. universities and colleges (National Science Foundation, 2016). The U.S. Department of Education has projected that there will only be a 14% increase in non-STEM related jobs between 2010 and 2020, whereas STEM-related jobs between 2010 and 2020 will increase by the following: 16% in mathematics, 22% in computer systems analysis, 32% in systems software development, 36% in medical science, and 62% in biomedical engineering (U.S. Department of Education, 2016). According to the 2013 *Federal Science, Technology, Engineering, and Mathematics (STEM) Education 5-Year Strategic Plan*, the funding needed to prepare students for these jobs includes Department of Education's initial support of $4.5 billion to states in order to meet three major objectives: the design of rich STEM curricula, the development of partnerships between STEM-related businesses and non-profit organizations, and an increase in women and minorities within STEM (Committee on STEM Education, 2013).

Despite the overwhelming demand for STEM graduates, retention of students in STEM higher education has been a challenge. According to a 2012 report by the President's Council of Advisors on Science and Technology (PCAST), the job market will experience a deficit of one million STEM graduates through 2022. Nevertheless, PCAST (2012) suggested that increasing the retention rate of STEM majors from 40% to 50% would meet three-quarters of the deficit.

In the process of reaching STEM education objectives and increasing retention, funding agencies have looked to educational strategies beyond the traditional teaching and learning methods that typically include in-person lecture teaching with rote memorization for the advancement of knowledge. Many of the new strategies are grounded in constructivist learning theory, which is characterized as fostering multiple perspectives, knowledge construction, and learning based on experiences (Jonassen & McAleese, 1993). In the realm of STEM education, constructivist practices have manifested themselves in different types of learning terminology, such as active learning, inquiry learning, problem-based learning, project-based learning, collaborative learning, creative learning, contextual learning, and reflective learning (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014; Hmelo-Silver, Duncan & Chinn 2007; Keengwe, Onchwari, & Agamba, 2014; Novak, 1998). Each of these learning and teaching practices have garnered much interest and financial support in STEM education. For example, as of June 2017, for research related to active learning (AL) alone there were 1,370 active NSF awards—121 of them being at least $1 million awards—and for research related to collaboration there were 30,617 active awards—2,424 of them being at least $1 million awards.

A focus of the research was on AL, which is defined as students actively engaging in the learning process through reading, writing, discussing, and being engaged in problem solving, all the while using higher-order thinking tasks of analysis, synthesis, and evaluation (Bonwell & Eison, 1991). Although the tenets of AL do not seem to be too innovative in general education, the process of AL has come to contrast against still common practices in science education, particularly in large-enrollment introductory courses, in which the instructor lectures and students take notes, read text, and take assessments rather than practicing higher-order thinking tasks (Kober, 2014). Concerning the effects of AL in science, engineering, and mathematics, Freeman and associates (2014) conducted a meta-analysis of 225 studies related to AL, and the results indicated that student examination performance increased close to half a standard deviation through AL and failure rates increased by 55% within a lecture-styled environment. The change in standard deviation translated to a 0.3 increase in the average final grade among students. Based on the results of the study, Freeman and associates (2014) argued that the increase in average final grade among STEM students would generate more “persisters” in STEM programs rather than “leavers,” for the National Center for Education Statistics (2012) had indicated that students with gaps of 0.5 and 0.4 in their STEM-course grade point average are more likely to leave a STEM program.

Active learning has occurred in face-to-face (FTF), online, or BL formats, but the scope of the dissertation study was limited to AL in BL environments. In higher education the definition of BL remains amorphous, which has been one reason there has been limited research to its affordances for the more studied learning and teaching strategies like AL. Within the study “affordance” is a term that focuses on “the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used” (Norman, 1988, p. 9). The study identified and investigated specific BL affordances—the perceived properties constituting and defining BL. On the surface level, BL is the blending of FTF and online time and activities (Graham, 2012). However, the operational definition throughout the study was that the affordances of BL are not merely the benefits of BL, but they include the perceived functions and overall experience of the student with the concrete examples of BL such as FTF lectures, online homework, and office hours. When viewing a course as a BL course, the blending can depend on the activities themselves such as the use of online discusses verses in-class discussions (Graham, 2006).

However, a more in-depth consideration of BL attempts to answer questions like: How much FTF time and online time is required to be considered BL? Does a blending of multimedia activities constitute as BL? What is the role of pedagogy in the definition? The literature review in Chapter 2 addresses such questions regarding definitions of BL, as well as AL, in higher education science courses. Due to the evolving definition of BL, it is difficult to determine exactly how many courses in higher education have a BL format. In 2006 Bonk, Kim, and Zeng surveyed 562 decision-making individuals in higher education, and at least 60% of respondents indicated that by 2013 at least 41% of student learning would be blended. In 2014 the research institute in which the study was conducted indicated about 43% of courses were blended (Cummings, 2016). Whether due to or as a result of, BL has shown potential to improve teaching and learning in higher education (Garrison & Vaughan, 2008). Means, Toyama, Murphy, Bakia, and Jones (2010) discovered in their meta-analysis that BL had a larger effect size in K-12 environments than purely FTF or online learning in those environments (+0.35, $p < .001$). The future of higher education needs additional research about how BL affects AL and vice versa. The conducted study answers the particular call for more research and rigorous assessment of BL in science education, with a specific focus on student retention (Stockwell, Stockwell, Cennamo, & Jiang, 2015). Furthermore, at the large research-intensive university where the study was conducted an Active Learning Initiative has been promoted across the campus, particularly through the cultivation of faculty discussion of AL practices and the conversion of classroom spaces for the facilitation of AL practices (Smith, 2016). A goal of the initiative is to develop higher-order thinking skills according to the revised Bloom's taxonomy such as evaluating as seen through checking and critiquing information and creating as seen through generating, planning, and producing (Krathwohl, 2002). The initiative follows Barkley's (2009) definition for AL: "Active learning means that the *mind* is actively engaged. Its defining characteristics are that students are dynamic participants in their learning and that they are reflecting on and monitoring both the processes and the results of their learning" (p. 17).

In response to BL affordances relative to AL, the final major component to the research is the consideration of the highly important student outcome of persistence. Concerning student retention, relevant variables have included self-efficacy, engagement, performance, and motivation. The study focused on student persistence, according to social and cognitive psychology's explanation that it is one manifestation of student motivation (Bandura, 1989). Following the Persistence Framework proposed by Graham, Frederick, Byars-Winston, Hunter, and Handelsman (2013), the study's definition of persistence in science education is the cyclical experience of confidence and motivation that leads the students to learn science and identify as a scientist, thereby keeping the students within science education. Thus, in the study student persistence is evident when students do not drop out of the enrolled introductory science course and stay on track to enroll in another science course. The study's conceptual framework is discussed in detail in Chapter 2.

Problem Statement

Despite rhetoric and funding for science in higher education to heavily support nontraditional teaching and learning strategies based on AL principles, insufficient research has been conducted regarding the affordances that formats like BL have on AL. More research is needed to explore how BL and AL are being practiced in today's undergraduate science courses—particularly in the large-enrollment blended courses that are required of all STEM majors at the beginning of their studies. As "gatekeeper" courses, these courses introduce students to STEM-related fields, and the class experiences encourage or discourage the students to keep a STEM-related major. An unfortunate phenomenon has occurred when students enter college with interest in STEM careers, but negative introductory course experiences have caused them to become disillusioned about the relevance of STEM education, thereby causing the students to feel unable to connect in-class problems with real-world ones and to lose motivation to further their studies in STEM education (Cromley, Perez, & Kaplan, 2015).

Purpose of Study

With the challenges related to retention in mind, this study explored whether and how various BL formats used in introductory science courses affected AL as an intervention for student persistence in science courses. Data from a multiple-case study, including data from a crafted measurement instrument, Blended Learning for Active Learning (BL4AL), captured BL characteristics related to AL that students consider conducive to their persistence in the course and in their program of study (see Appendix F for an initial draft of BL4AL).

Research Questions

The research focused on BL's effects on AL, rather than AL in BL environments. The priority was to explore the role of BL in relation to AL rather than AL performances within BL. Specifically, this study addressed the following research questions:

1. How do BL affordances for AL practices manifest in introductory science courses?
2. According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?

Research Objectives

The research objectives were to:

- Identify characteristics of a BL format conducive to AL;
- Explore how AL is being implemented in undergraduate science courses using a BL format;
- Develop an instrument that helps to capture the effects of BL on AL for student persistence;
- Identify instructional design best practices of BL and AL for student persistence in introductory science courses.

Research Design Overview

Due to the limited research related to BL affordances for AL for student persistence, the study took an investigative approach and followed an embedded, or nested, mixed methods design, in which quantitative data collection and analysis augmented qualitative data collection and analysis (see Figure 1-1).

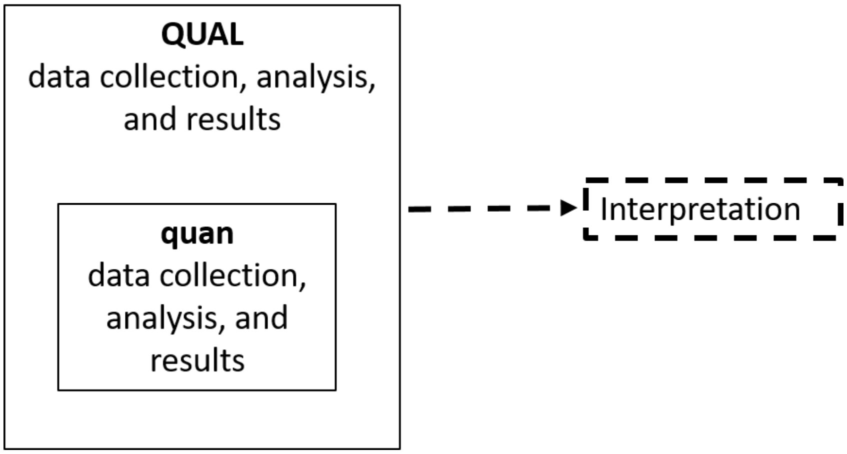

Figure 1-1. Illustration of embedded mixed methods design (Plano Clark & Creswell, 2010, p. 309).

The design allowed for a richer investigation to what factors of BL affect AL through the use of both qualitative and quantitative methods (Plano Clark & Creswell, 2010). More specifically, because the research questions focused on introductory science courses, this study examined two cases: an introductory chemistry course and an introductory physics course. Thus, the study followed a mixed methods design that mixed a multiple-case study with a survey administered to each course—the purpose of doing so being to address the complicated questions related to BL, AL, and student persistence (Yin, 2014). The qualitative research methods of interviews, observations, and documentations contributed to a case, as did the results from the quantitative data collected through a developed survey and statistically analyzed.

At the theoretical level, Schramm (1971) describes "the essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result" (p. 6). The methodology then was appropriate to use in the quest to answering how BL affordances for AL are manifested in the courses and how the affordances affect AL for student persistence. On a more practical level, the operational definition of case study used is an empirical inquiry that investigates when there is “a contemporary phenomenon (‘the case’) in depth and within its real-life context, especially when the boundaries between phenomenon and context may not be clearly evident” (Yin, 2014, p. 16). The case study was a most appropriate design to consider the effects of BL on AL as a contemporary phenomenon in introductory science courses, to explore the boundaries among the amorphous concepts of BL, AL, and student persistence, and to be carried out with multiple sources of evidence through observations, interviews, and documentations.

In order to understand the occurrences within a course, the course was chosen to be the unit of analysis. Rather than focusing on BL affordances for AL in only one course, two courses were investigated—PHY 2048: Physics with Calculus 1 and CHM 2046: General Chemistry 2. Instructors and students involved in those courses were interviewed, and questions in the interview protocol for both instructors and students (see Appendices A and B) were written according to the study’s conceptual framework, which is detailed in Chapter 2. The framework was based on Graham’s (2006) dimensions of BL, Meyers and Jones’ (1993) AL structure, and Graham and associates’ (2013) Persistence Framework. The argument behind the framework was that the dimensions of time, fidelity, humanness, and space constitute BL within a course (Graham, 2006), and those dimensions enable or constrain the AL structure in a course. The AL structure consisted of (a) basic elements for higher-order thinking including talking and listening, writing, reading, and reflecting and (b) teaching resources (e.g., readings and homework assignments) feeding into (c) learning strategies (e.g., simulations and small groups; Meyers & Jones, 1993). The resulting BL-AL relationship then became a catalyst within Graham and associates' (2013) Persistence Framework, driving student's confidence, student motivation, science learning, and identifying as a scientist.

Because the participating courses were volunteered, the practices of BL and AL in the participating undergraduate science courses were already designed before the study and implemented without the researcher’s influence and recommendations. Semi-structured interviews were conducted with the lead instructors of the courses. Student volunteers were chosen based on their academic performance in the course. As a way to collect diverse feedback, from each course the researcher chose to interview two students who were low performing (having a C or lower letter grade in the course at the time when volunteers were requested), two students who were average performing (having a letter grade from a C+ to a B), and two students who were higher performing (having a letter grade from a B+ and A+).

In addition to the interviews were observations of class activities in both the in-person and online course formats and a review of documentations, including course syllabi and other course materials. An audit trail detailed the chronology of major research steps and documented the reasoning behind critical decisions. The qualitative data underwent content and thematic analyses, and a codebook was maintained during the iterations of coding (Bazeley, 2013). A conceptual map and summary of the emerging themes were included in a final report of the data analysis in order to connect the coding results. More details about the qualitative research process is included in Chapter 3.

In addition to the qualitative data collected and analyzed, quantitative data was collected through a survey and analyzed statistically via MPlus™ and SPSS™. The results from the literature review, influenced the development of the items on the BL4AL survey—the main component of the quantitative phase of the study. The survey instrument included items influenced by Eddy, Converse, and Wenderoth's (2015) four dimensions of best practices for AL as seen in the classroom observation tool Practical Observation Rubric To Assess Active Learning (PORTAAL; see Table 3-1) and Johnson and McClure’s (2004) version of the Constructivist Learning Environment Survey (CLES), also called CLES 2(20) (see Appendix E). The inferences and the uses of both instruments have exhibited degrees of validity. In the design of BL4AL the items were organized according to Graham and associates' (2013) four elements of student persistence (i.e., student confidence, student motivation, science learning, and identifying as a scientist) because the study's argument was that the BL influencing AL is interconnected with student persistence (see the study’s conceptual framework in Figure 2-8). In each category relating to student persistence were eight statements, or items, and each item expressed a dimension of BL (Graham, 2006) and a component of the AL structure (Meyers & Jones, 1993). When rating each statement, the students did so on two five-point Likert scales from 1 Strongly Disagree to 5 Strongly Agree; one scale represented the students' perceptions of a statement regarding traditional learning methods, while the other represented the student's perception of a statement regarding nontraditional learning methods (see draft in Appendix F).

The quantitative data collected followed recommended protocols for a confirmatory factor analysis (CFA) due to *a priori* expectations (Floyd & Widaman, 1995). The BL4AL was shared with instructors as subject matter experts who assisted with the content validity of the instrument by rating whether questions did not, partially, or adequately represent student confidence, student motivation, science learning, or identifying as a scientist. Undergraduate students not associated with the course assisted with the face validity of the instrument, and a final draft of the survey was administered to students before their final exams. Descriptive data from BL4AL from each course was used to describe the students' perceptions of that particular BL implementation on AL in the course. Multiple linear regression analysis was conducted with the average scores from each category of a persistence factor with traditional or nontraditional learning methods as the predictors and the students' indication of whether the course motivated them to persist in the sciences as the outcome. More details about the research design, including the locations and timeline of the research, are explained in Chapter 3.

Assumptions

It was the assumption of the researcher that STEM is and will continue to be an area of interest in U.S. higher education. Within STEM education, the practice of BL formats will continue to increase—contributing to more advanced definitions of BL within science education as the current definition of the term simply and primitively remains a course with some activities being online and some FTF (Baepler, Walker, & Driessen, 2014; Graham, 2012; Picciano, 2009). Furthermore, based on the findings of previous research (Freeman et al., 2014), another assumption was that AL practices are more effective for student performance and student retention in undergraduate STEM education when compared to traditional, non-AL teaching practices that depend more so on transmitting information from the instructor to students via lectures.

Limitations

Due to the exploratory nature of the study, it has been challenging to identify all the limitations to the study. The major concern was the capture of the affordances of BL on AL and how they influence student persistence. Because the study focused on BL and AL, which are two highly ambiguous and ill-defined concepts, there was the challenge of providing operational definitions. Student persistence was also a complex term, which made it difficult to measure as the overall latent variable.

Courses in the study were volunteered by the instructors, so the occurrences within non-volunteered courses were not be captured. Additionally, only instructors and students who volunteered were interviewed, and what they said influenced questions on the BL4AL. However, to minimize bias, the researcher followed best practices for the interviewing process, and interviewed students representing varying levels of class performance.

Scope and Delimitations

For the scope of the study, the courses were housed within a large research institution in the Southeast, which, although diverse, may not represent the experiences of other courses at other institutions. Rather than focusing on all STEM-related courses, the researcher focused only on volunteered science courses, which included physics and chemistry. Additionally, only introductory-level courses were considered due to retention in those courses being more critical for the whole of the respective programs (Kober, 2014). Because concentration were on the affordances of BL on AL, no data were collected from purely FTF or online versions of the courses.

Significance of the Research

One goal of the researcher was to fill gaps in the literature concerning the affordances of BL on AL, as well as how the affordances influence student persistence. Such research has the potential to contribute to the implementation of key administrative and instructional design decisions related to best classroom practices in STEM education. In Drysdale, Graham, Spring, and Halverson's (2013) study of dissertations related to the study of BL, they reviewed 205 dissertations and found that 34.6% of the dissertations focused on instructional design; out of those, only 5.9% focused on implementation of best practices in BL. The results from the presented study helps to narrow the gap in the literature related to the implementation of instructional design in the BL environment.

Additionally, the influence of BL as a practice in higher education needs further examination. Graham, Allen, and Ure (2005) have pointed out that BL has most prominently met three goals: the advancement of effective pedagogy, more convenience for students and instructors, and increased cost effectiveness. The positive effect of BL on student engagement and class performance still remains debatable. Baepler and associates (2014) in their experimental study and Means and associates in their meta-analysis (2010) discovered that BL positively influences learning outcomes. However, other studies (e.g., Bowen, 2012) have also shown that BL has had no significant effect on learning outcomes. Rather than supporting an abandonment of BL, the argument is that “no significance” indicates that BL does not produce subpar learning outcomes, and its potential benefits, including learning outcomes and the subsidization of costs, should continue to be considered. This is very similar to the early research comparing the effects of distance learning and FTF learning.

Presenting the pedagogical practice of AL in relation to BL particularly affords the possibility for significant research related to BL as a whole. In order to prevent the creation of what Clark (1983) would argue an insignificant media study, the study reviewed the pedagogical practices of AL as the “active ingredient[s] in learning” while the affordances of BL enabled or constrained particular AL practices (Graham, 2013, p. 340). Framing the study of BL with the pedagogy related to AL allowed more explicit findings and recommendations compared to studies that focused on BL in isolation, which have often produced more general results and recommendations (Graham, 2013).

In addition to the academic benefit of the research, there is also financial benefit. The pressures of cost effectiveness and the trend to change have influenced the adoption and implementation of BL (Graham, Woodfield, & Harrison, 2013). Administrators in higher education have been combatting a variety of financial pressures, including “cost disease” – a theory postulated by Baumol and Bowen (1966) that institutions like universities do not have direct profits from rapid technological advances but still need to pay higher societal costs driven by a myriad of institutions who do have more immediate financial benefits from technological advances (Baum, Kurose, & McPherson, 2013). To utilize technology to subsidize costs, administrators have turned to online education (Deming, Goldin, Katz, & Yuchtman, 2015) and BL (Graham, 2012) as possible solutions. Within BL environments fewer physical seats are required and in-classroom time with its costs of maintenance is decreased (Baepler et al., 2014; Gonzalez, 2014). The benefits of cost effectiveness can lead to more convenience in access to learning and more flexibility with the time taken to learn

(Graham, 2012). The results of this study's investigation of BL for AL contributes to more research needed about the affordances of BL for AL (Graham et al., 2013). Although AL has been attractive to instructors, researchers, and funding agencies, research remains lacking as to how the practices of BL enable or constrain AL and, thereby, to how the practices influence student persistence to remain in STEM education.

Dissertation Roadmap

The researcher first acknowledges that highly discussed, amorphous areas of academic study – AL, BL, and student persistence—are being studied. In the sciences AL has been manifested in such learning techniques like inquiry learning, problem-based learning, project-based learning, collaborative learning, creative learning, contextual learning, and reflective learning (Freeman et al., 2014; Hmelo-Silver, Duncan & Chinn 2007; Keengwe, Onchwari, & Agamba, 2014; Novak, 1998). Although BL in general has been challenging to define, BL in the sciences has often been simply the blending of FTF and online time and activities, showing that BL in the field is still at its infancy (Baepler et al., 2014; Gonzalez, 2014; Picciano, 2009; Stockwell et al., 2015). Discussion in Chapter 2 focuses on literature providing the general and STEM-related definitions and applications of and research related to BL and AL, as well as the connections between BL and AL on student persistence. The influence of AL through BL as a contributing factor to student persistence is detailed in Graham and associates' (2013) Persistence Framework. The review of the literature leads into the construction of the conceptual framework for the research.

Discussion in Chapter 3 details the mixed methods research design as seen in the multiple-case study and survey. The researcher describes the courses and participants, the methodology, and the more specific methods for data collection. Plan for data analysis is provided in Chapter 3, and findings are presented in Chapter 4. In Chapter 5 the researcher discusses the results and presents the implications of the study and conclusions based on the study's results.

CHAPTER 2
LITERATURE REVIEW

While creating a conceptual framework for the investigation of BL affordances for AL for student persistence, three predominant, foundational questions arose: (a) How is AL being defined? (b) How is BL being defined? (c) How can student persistence be defined in relation to BL and AL? Although researchers have not agreed on crystallized definitions for the terms of AL, BL, and student persistence, this chapter discusses how the terms have been defined and how the three influence each other in science education. Thus, the purpose of this chapter is to define the key terms and discuss relevant conceptual and empirical literature related to the key concepts. The resulting conceptual framework as the basis of the research design establishes how AL is the driving pedagogy being influenced by the properties of BL and how the constraint and enablement of BL on AL determines student persistence. It is the argument of the researcher that AL can exist via multiple types of media; however, it may reach its potential through the properties of BL, thereby becoming more influential in the cycle encouraging student persistence.

Active Learning in Undergraduate Science Education

This section discusses the existing definitions of AL, introduces the present focus on AL and its benefits, and describes examples of AL manifestations in undergraduate science education.

Definitions for Active Learning

Understanding the history of AL leads to a better understanding of its definition. Active learning as an instructional approach is one of the many instantiations of constructivism, a popular learning theory that emphasizes a view of learning and knowing based on people constructing their own understanding and knowledge of the world through experiencing things and reflecting on those experiences (Piaget, 1950). Simply, AL has been defined as “any instructional method that engages students in the learning process” (Prince, 2004, p. 1). Empirical evidence from decades of classroom research demonstrates that students who actively engage with course material end up retaining it for much longer and applying it to real-world problems than they would have when taught using the traditional, direct instruction approach (Waldrop, 2015).

Although not very novel at all to education, the term AL became popular in the early 1990s when the idea for AL contrasted with the general observation of a lack of excitement in the classroom—the prevalent belief among teachers being that the students listening to a lecture was adequately engaging (Bonwell & Eison, 1991). In response to the status quo of the times, Chickering and Gamson (1987) synthesized seven good practices to be emphasized in undergraduate education: (a) more contact between students and faculty; (b) reciprocity and cooperation among students; (c) AL techniques in the classroom; (e) prompt feedback; (f) emphasis of time on task; (g) communication of high expectations. However, the recommendation for AL techniques in the classroom remained unclear. Bonwell and Eison (1991) attempted to disambiguate AL through establishing key characteristics to AL:

- students engaging in activities beyond listening such as reading, writing, and discussion;
- instructor emphasizing the development of skills rather than the transmission of information;
- students participating in higher-order thinking like analysis, synthesis, evaluation; instructor encouraging students to explore their own attitudes and values during the learning process.

Beyond the establishment of AL characteristics, Meyers and Jones (1993) developed a framework showing the interrelationships between the basic elements, learning strategies, and teaching resources for AL (see Figure 2-1).

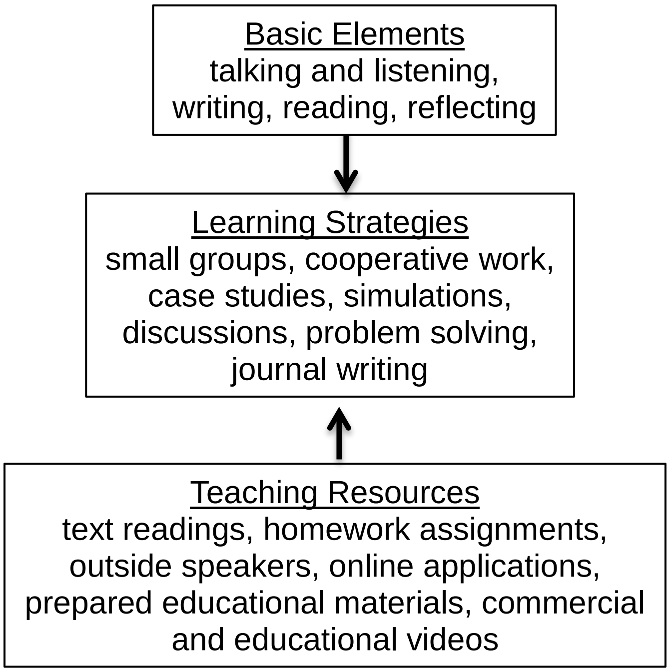

Figure 2-1. Meyers and Jones' (1993) proposed structure for active learning.

The basic elements require higher-order thinking coupled with physical action, and the elements feed into the learning strategies. The learning strategies engage the students beyond merely reading, writing, and discussion by making the experiences more authentic through interactions with others, case studies based on real-world experiences, and a reflection of one's own attitudes and values. Similar to the elements, the teaching resources feed into the learning strategies. Because the recommendations were made in 1993, technology has advanced that blogging may replace journal writing, online videos for commercial and educational television, and more emphasis can be made on virtual simulations. The interweaving of the basic elements and teaching resources into learning strategies produces a more operational definition of AL rather than merely stating AL is not a traditional learning method, in which the instructors shares information while students passively receive.

Present Emphasis on Active Learning

Since the early 1990s, the definition and characteristics of AL have not radically changed in undergraduate science education. Outside of learning in the laboratory, traditional lecturing remains a common practice among instructors of undergraduate science classes, and, opposite to the traditional lecturing, AL is the "diversification of teaching methods" for the future of undergraduate science education (Kober, 2014, p. xii). In order to compare AL to traditional instruction (i.e., lecture plus quizzing), a key piece of research has been Freeman and associates' (2014) meta-analysis of 225 studies comparing examination scores and failure rates of undergraduate students within STEM-related fields in AL courses versus lecture courses. In their findings, when the practice of AL was employed, student examination performance increased close to half a standard deviation. Compared to an environment with AL, failure rates increased by 55% within a lecture-based environment. Furthermore, the increased examination performance with AL and increase of failure rates with lecture-based learning could be seen across all STEM disciplines and within all course sizes, course types, and course levels. To highlight the importance of the findings, Wieman (2014), a Stanford University professor awarded a Nobel Prize in Physics, noted the results of the meta-analysis implicated that AL could impact educational outcomes in a large and consistent way—also pointing out that the argument of no longer using lecture teaching as an appropriate comparison standard is a consideration that should no longer be ignored.

Because the term AL refers to a group of constructivist instructional methods rather than a single pedagogy, when searching for literature related to AL, Freeman and associates (2014) included terms like constructivism, cooperative learning, collaborative learning, inquiry-based learning and problem-based learning. Thus, rather than the learning methods being different from each other, AL became the umbrella term for similar learning methods that are more student-centric with the instructor being a “guide on the side” compared to the “sage on the stage” in traditional lecturing. In order to better understand AL in undergraduate science education, it is best that a more lengthy exposition of its constituents be considered. The following will not discuss all concepts and terms that could be related to AL; however, it does present many of the most commonly associated notions, such as constructivism, active learning itself, inquiry learning, problem-based learning, and project-based learning (Prince & Felder, 2006).

Review of Active Learning and Constructivism

Active learning has strong roots in the learning theory of constructivism. The term *constructivism* and the arguments for the learning theory have been often used and debated in the field of education and psychology; however, the use of the term and of the concepts behind the term is in the process of growing (Duit, 2016). Learning methods having constructivist characteristics have included: active learning, inquiry learning, problem-based learning, and project-based learning among others (Freeman et al., 2014; Hmelo-Silver et al., 2007; Keengwe et al., 2014; Novak, 1998; Prince & Felder, 2006).

Constructivism also does not have a clear-cut definition, as different definitions emphasize an individual’s knowledge construction (cognitive constructivism) or social co-constructions (social constructivism) (Gijbels, van de Watering, Dochy, & van den Bossche, 2006; Loyens, 2007; Loyens & Gijbels, 2008; Piaget, 1967; Vygotsky, 1978;

Windschitl, 2002). Nevertheless, a commonality among definitions has been that constructivism is “a view of learning that considers the learner as a responsible, active agent in his/her knowledge acquisition process” (Loyens, 2007, p. 16). It should be noted that because constructivism proposes that students take ownership and actively engage in their own learning, that does not mean that constructivist teaching and learning practices encourage unguided discovery learning and the students do whatever they want. Mayer (2004) conducted literature reviews regarding constructivist teaching and learning, and argued that “the formula *constructivism = hands-on activity* is a formula for educational disaster” (p. 17). He had evaluated constructivism according to Lefrancois’s (1997) definition of constructivism as a teaching approach in which students construct knowledge for themselves through discovery. Nevertheless, when the discovery process has been guided and proper scaffolding based on theory and empirical research has been employed, constructivist learning environments have proven to be effective (Collins, Brown, & Newman, 1989; Davis & Linn, 2000; Golan, Kyza, Reiser, & Edelson, 2002; Guzdial, 1994; Hmelo & Guzdial, 1996; Hmelo-Silver, 2006; Hmelo-Silve et al., 2007; Jackson, Stratford, Krajcik, & Soloway, 1994; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, et al., 2004; Reiser, 2004; Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001; Toth, Suthers, & Lesgold, 2002).

In order to better understand AL, the next sections discuss its constructivist lineage as seen through inquiry learning, problem-based learning, and project-based learning. It should be noted again that the learning methods may not be pure derivatives of constructivism (e.g., cognitive learning theory can be seen in many of the methods); however, the constructivist properties of the learning methods are areas to focus upon according to the study’s scope. Figure 2-2 shows the proposed relationships between constructivism, AL, and manifestations of AL.

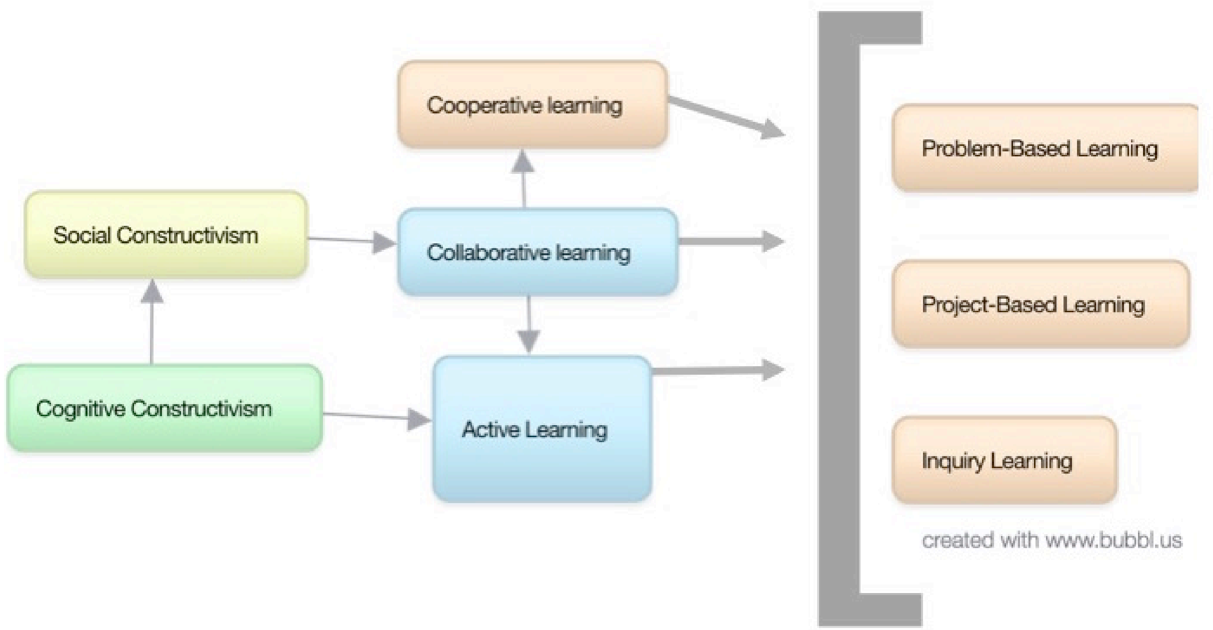

Figure 2-2. Relationships between cognitive constructivism, social constructivism, and active, collaborative, cooperative, inquiry, problem-based, and project-based learning.

As seen in Figure 2-2, AL has roots in cognitive constructivism and influenced by collaborative learning, including cooperative learning; in the various sciences it can be manifested through the learning methods of inquiry, problem-based, and project-based learning, which is always active and usually, but not always, collaborative or cooperative (Prince, 2004). For the scope of the literature review and the study, cooperative and collaborative learning are not being discussed in detail due to their being more associated with the tenets of social constructivism (e.g., the focus being on group work for knowledge construction; Puzio & Colby, 2013; So & Brush, 2008; Vygotsky, 1978). Although the study did not ignore data about social interactions during AL in a BL environment, the study’s focus was on the individual learner’s experience of AL within

BL rather than an examination of a group's experience related to collaboration or cooperation.

It is important that the manifestations of AL are discussed because reports of the benefits of AL have also included manifestations such as inquiry learning, problem-based, and project-based learning (Freeman et al., 2014; Kober, 2014). Thus, more explanation and examples about AL, inquiry, problem-based, and project-based learning are conveyed in the chapter. The following sections are divided into two parts: an introduction to the particular learning method and research examples of how the method is practiced in specific disciplines in the sciences. The examples shared with each method are not meant to all-inclusively show how the method is used in a discipline but are meant to provide a representative example of how the method has been implemented in a discipline.

The general goals for using the instructional methods among the science classes in any discipline are not that different—essentially, students being more engaged, developing relevant skills such as scientific inquiry and experimentation, and exercising higher-order thinking such as analysis, synthesis, evaluation, and application. However, the consideration of the interdisciplinary differences in practice can contribute to discussion related to discipline-based education research (DBER) and inquiry learning, which the National Research Council (2012) has deemed critical to providing foundational science knowledge to students, motivating them to finish science-related degrees, and providing those with science-related degrees the necessary knowledge and skills to be successful. Being grounded in the sciences, DBER is an enterprise that investigates teaching and learning in a specific discipline in order to better understand the discipline’s priorities, worldview, knowledge, and practices (National Research Council, 2012).

Examples of Active Learning in Undergraduate Science Courses

Of all the terms related to constructivism, AL has been one of the most popular terms used when describing a science class’ attempt to proceed unconventionally (Jensen, Kummer, & Godoy, 2015; Laws, Sokoloff, & Thornton, 1999; Michael & Modell, 2003; Modell & Michael, 1993; Prince, 2004). Being opposed to purely lecture-based methods, AL has been used in research in multiple science disciplines. The following are examples demonstrate various ways AL has been implemented in undergraduate science courses.

Haak, HilleRisLambers, Pitre, and Freeman’s (2011) study of student performance in a high enrollment, introductory biology course over 29 quarters describes a combination of creating a highly-structured course, in which the use of peer-instructed format and AL reduced the achievement gap between advantaged and disadvantaged students. Following a similar structure to a flipped class, the peer-instructed format focused on in-class discussions between the instructors and students concerning student-generated questions from readings before class; throughout the process, the instructor determines whether the students are ready to move on to a different topic (Mazur, 1997). The AL activities included daily, multiple-choice questions requiring students to use clickers, and weekly practice exams with five short-answer questions that were peer-graded. The highly-structured course particularly benefited the disadvantaged students, as seen with the likelihood ratio test—with those students in the university's Educational Opportunity Program as the fixed effect—resulting in df = 13, χ^2= 10.997, p = .0027.

Kober's (2014) discussion of a case study of an introductory course to physical geology focused on AL activities that include the use of clickers in response to multiple-choice questions in class. In addition the use of clickers, there was immediate peer discussion to verify which answer is correct and why. The instructor noted he himself was encouraged to see students engaging in discussions. The students also benefited in that, for example, 44% of the students were able to respond to a particular question correctly. Through the AL activities 75% of the students were able to answer the question correctly.

Jensen, Kummer, and Godoy's (2014) study of an introductory biology course for nonscience majors compared whether students performed better in a flipped class with AL compared to a non-flipped class with AL and whether students had better attitudes in one of the designs. Active learning followed Bybee's (1993) 5-E learning cycle: engaging the student to consider a topic based on their interests (e.g., a puzzling phenomenon), student exploration of content related to the topic, explanation of the topic for concept-building (e.g., mini-lectures), elaborating on teaching and learning by asking students to solve higher-order problems compared to previous problems, and evaluating student knowledge through quiz-taking using clickers or a unit exam. As a part of the quasi-experimental study, the students completed the 24-question Lawson Classroom Test of Scientific Reasoning (LCTSR) in order to assess their scientific reasoning skills. The results showed that students did not perform better in or favor flipped or non-flipped classes, as long as AL existed in the class ($M_{non-flipped}$ = 18.2, $M_{flipped}$ = 19.5, $t(90) = 1.58$, $p = .12$).

Active learning has been the incorporation of engaging the students during a lecture, most often in large classes because the lecture method historically has been the predominant method in practically overseeing them. Although the examples illustrate AL as student activities using clickers and having peer discussions, literature has shown that the practices found in inquiry learning, problem-based, and project-based learning stem from AL (Freeman et al., 2014; Michael, 2006; Prince, 2004).

Active Learning through Inquiry Learning

Inquiry learning, or inquiry-based learning, is a learning method in which students collaboratively engage in investigations related to a discipline-based content (often in the sciences), thereby building reasoning skills and practices in that discipline (Hmelo-Silver et al., 2007). The focus of inquiry learning is scientific inquiry in which students pose questions, collect and analyze data, and make evidence-based conclusions (Kuhn, Black, Keselman, & Kaplan, 2000; Krajcik & Blumenfeld, 2006). Originating in chemistry education, the Process Oriented Guided Inquiry Learning (POGIL) requires that data or information first be presented to the students, and students through answering leading questions make their own conclusions—throughout the process the students work in small groups while the instructor acts as a facilitator (Kober, 2014; Process Oriented Guided Inquiry Learning, 2014). It has been argued that the questions involved in the learning process be real-life problems to authenticate the learning experience; otherwise, students undergo the inquiry learning process in isolation from the real world and cannot apply the knowledge they have learned when needed (The Design Principles Database, 2007). Technological developments have been made to help simulate learning environments for inquiry learning (van Joolingen, de Jong, & Dimitrakopoulou, 2007). Additionally, the instructor as facilitator is not a passive role but an active one, demanding the instructor to exercise scaffolding and direct instruction when needed (Hmelo-Silver et al., 2007; Krajcik, Czerniak, & Berger, 1999; Schmidt, 1983; Schwartz & Bransford, 1998).

Examples of Inquiry Learning in Undergraduate Science Courses

Talanquer and Pollard's (2015) NSF-funded project to redesign chemistry curriculum produced a self-case study of an introductory chemistry course, describing a multi-phase effort to train students to think more like chemists. The course instructors used POGIL to gradually redesign the curriculum. About 300 students were broken down into small groups, and were given more objective chemistry problems to solve (e.g., how changes in water molecules would affect the properties of water, the earth's climate, and life on the planet). Rather than merely memorizing formulas, the students created their own simulations and models based on the formulas. In order to evaluate the project, the students who underwent the new curriculum and those who underwent the regular curriculum completed an American Chemical Society (ACS) exam, and there was no significant difference between the two group—the average of the new curriculum group being 60.6% versus the average of 60.8% among the regular group. However, the researchers did note the no significant difference was a positive outcome in that the new curriculum did not focus on algorithmic problem solving, which is a major component on the ACS exam. When the two groups completed the conceptual chemistry questionnaire, there was a significant difference between the regular group who scored an average of 44.3% and the new curriculum group who scored an average of 55.3%—the t-test resulting in $p < .01$.

Williamson, Huang, Bell, and Metha's self-case study (2015) of introductory chemistry courses discusses how a pathway of courses (i.e., fall, spring, and summer introductory courses) underwent a redesign according to POGIL. The instructors shared about five slides of content knowledge before students broke into their groups to review information, answer a series of critical-thinking questions, and shared their answers with others in the group. Instructors and their assistants circulated around the auditorium to answer questions. In response to the redesign, students indicated they had positive experiences, especially with 81% satisfied with the feedback given. Proportionally, there were more students with higher grades in 2012-2014 than before the redesign in 2012. Students in the cohorts during the redesign also have moved on to higher level chemistry courses; for example, 26 out of 38 students in the 2015 cohort moved on to higher-level chemistry courses.

Parappilly, Siddiqui, Zadnik, Shapter, and Schmidt's (2013) study of the laboratory in introductory physics course for nonscience majors encouraged students to plan and execute their own experiments within an inquiry-based laboratory session that was designed and interjected into the laboratory schedule at two universities. The students underwent three to four traditional laboratory sessions and one inquiry-based session (for University A the inquiry-based one was session three, and for University B session five). As a result, out of 32 students at University A 69% indicated they liked the inquiry-based laboratory, 79% reported being more challenged in their thinking and analysis during the inquiry-based laboratory, and 63% of students indicated they learned more. At University B out of 32 students 84% indicated they liked the inquiry-based laboratory, 63% reported being more challenged in their thinking and analysis during the inquiry-based laboratory, and 84% indicated they learned more. Their laboratory reports in the inquiry-based laboratory scored higher compared to their scores for the other reports in the traditional laboratory format, and their examination scores stayed the same compared to their work after a traditional laboratory session. Although the novelty effect due to only one inquiry-based session is a possible influence of the results, more research, especially related to student motivation, is needed to evaluate the potential of an inquiry-based laboratory. From the qualitative data collection, some of the students reported not favoring the inquiry-based laboratory because they did not feel capable to design their own experiments. The frustrations indicated that more scaffolding needed to be added to the laboratory experience.

Active Learning through Problem-Based Learning

Originating from medical education (Woods, 1996), problem-based has been defined as a learning method in which “students learn content, strategies, and self-directed learning skills through collaboratively solving problems, reflecting on their experiences, and engaging in self-directed inquiry” (Hmelo-Silver et al., 2007, p. 100). Different from inquiry learning, which focuses more on scientific inquiry, an emphasis of problem-based learning is the building of the student’s ability to understand the processes required to understand and address a real-world problem, while regulating learning and reflecting through collaborative, AL activities (Hmelo-Silver, 2004; Lu, Bridges, & Hmelo-Silver, 2014). The emphasis on the solving of complex, ill-structured problems is central to this approach (Barrows, 2000; Savery, 2006). As the well-known philosopher of science, Karl Popper (1999), noted, “all life is problem solving.” Through attempts to solve challenging problems, the students are put into situations in which they need to share their knowledge, negotiate possible solutions, search for more information, and provide evidence-based conclusions (Lu et al., 2014). Aside from the influence of active learning in general, problem-based learning also has been highly influential across disciplines and different levels of education (Savery, 2006). However, the popularity of problem-based learning has not always produced positive results when there have been the following: confusion about the learning method being an approach to curriculum design versus a teaching method to problem solving, insufficient commitment from faculty, lack of the development of the problems to be solved, and lack of resources to support problem-based learning (Boud & Feletti, 1997; Savery, 2006).

Examples of Problem-Based Learning in the Sciences

Tosun and Taskesenligil's (2013) study of an introductory chemistry course examined 42 students in the treatment group who underwent a five-week intervention of problem-based learning activities in the course, while another 42 students (the control group) attended lecture-based classes. Scenarios were developed by the researchers to act as the problems for the problem-based learning activities. An instructor trained in active learning and problem-based learning worked with the students, and the class time took place in the laboratory rather than a lecture hall. To prepare the students for problem-based learning, the researchers provided the students a manual about problem-based learning and asked the students to divide responsibilities among themselves (e.g., leader, recorder, timekeeper, and reflector). The students completed a pre-test in which the control group had a higher mean (M = 37.34, SD = 12.022) than the experimental group (M = 33.14, SD = 7.798), although the difference was insignificant ($t(69) = -1.753$, $p > .05$). After the intervention, the experimental group had a higher mean for the post-test (M = 73.86, SD = 10.232) than the control group (M = 62.23, SD = 15.051), which was significant ($t(69) = 3.818$, $p < .05$). The students who completed problem-based learning activities were better in accessing and using knowledge learned, working in groups, autonomous learning, and problem solving. The researchers did report challenges with problem-based learning included setting up heterogeneous learning groups, encouraging cooperation in the groups, dealing with competition among group members, and the time needed to complete activities during class.

Montgomery and Donaldson’s (2014) self-case study focused on an introductory paleontology course for 20 honors students. The researchers/instructors followed problem-based learning by incorporating a driving question at the beginning of every class and reducing lecture to allow students to discuss with their peers and collectively problem solve. Markham, Larmer, and Ravitz’s (2003) *Project Based Learning Handbook* was used as a guide. Crafting the questions was a deliberate process, in which considerations were made regarding whether students would be able to respond with authentic artifacts like conference presentations, whether the questions were sufficiently complex and ill-structured, and whether course objectives were being met. Students exhibited self-reflection through a journal and modified PechaKucha presentations (quick presentation activity in which students are only allowed to present 10 slides, 15 seconds each).

Stockwell and associates’ (2015) conducted a randomized trial of BL, in which 111 students in an introductory biochemistry course participated in the two-by-two study design of video versus textbook assignments before class and instructor-demonstrated problems versus lecturing plus student problem solving in class. For randomization the students were stratified according to gender and their prior exam performance. In the study BL was defined as the blending of different media and teaching methods. The students were put into one of four groups: (1) textbook preparation for traditional lecture, (2) video preparation for traditional lecture, (3) textbook preparation for lecture plus student problem solving, and (4) video preparation for lecture plus student problem solving. Among the four groups, those who were assigned the video preparation were more likely to attend class—47 out of 56 students attended class compared to the 37 out of the 55 students from the groups with textbook preparation ($p = .04$, Pearson's chi-square test). Students were also more satisfied to receive video preparation (4.3/5.0) versus those who received textbook preparation (2.9/5.0) ($p < .0001$, Mann-Whitney test). However, focusing on the addition of problem solving into the class activities, that became the most significant intervention in that the median score on the exam was the higher for those with problem solving (74/100) than the group with lecture only with either preparation type (63/100) ($p = .03$, Mann-Whitney U test).

Active Learning through Project-Based Learning

Project-based learning has been confused with problem-based learning, which is understandable since it also encourages driving questions, focuses on learning objectives, and requires knowledge exploration, collaborative activities, scaffolding, and the creation of tangible products (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991; Krajcik, Blumenfeld, Marx, & Soloway, 1994; Krajcik & Czerniak, 2013). Teamwork among the students is essential, in that the diverse knowledge and skills from team members can contribute to more meaningful results than individual decisions (Frank, Lavy, & Lata, 2003). Project-based learning came into being as researchers in Denmark worked to develop the pedagogy for the use of projects in engineering education (Algreen-Ussing & Fruensgaard, 1990; Berthelsen, Illeris, & Poulsen, 1977;

Graaff & Kolmos, 2007; Holten-Andersen, Schnack, & Wahlgren, 1983). Project-based learning has been defined as situated learning “based on the constructivist finding that students gain a deeper understanding of material when they actively construct their understanding by work with and using ideas” (Krajcik & Shin, 2014, p. 275). Practical differences have been that project-based learning does not depend on a complex, ill-structured question as problem-based learning does (Montgomery & Donaldson, 2014) and that more focus be on the project itself and the creation of a tangible product as a representation of learners’ knowledge (Thomas, 2000). Originating with Dewey (1959), who advocated that students work on meaningful assignments similar to ones that would occur in a real-world situation, project-based learning became grounded in the ideas of active construction, situated learning, social interactions, and cognitive tools (Krajcik & Shin, 2014).

Examples of Project-Based Learning in the Sciences

Frank and associates’ (2003) qualitative study considered the perceptions and attitudes of freshmen in an introductory project-based learning course in engineering. Thus, rather than project-based learning being added to an already established course, a course was constructed to focus on the learning method. In the 14-week course the students had four major design projects related to mechanical engineering, and one of the goals of the course design was to encourage students to feel more like engineers. Students worked in teams, and were encouraged to use any resource to help them in the process, including Internet materials, graduate students, teaching assistants, and the faculty. Among all the persons participating in the course, 11 were interviewed for data collection, and the transcribed interviews underwent the various levels of coding. As a result, six major themes emerged. It was discovered that in general the students’ perceptions of the course goals aligned with the course instructor's aims, but the course lecturer expressed frustration in changing traditional lecture styles to match the practices of project-based learning in which the instructor or lecturer has more of a role of mentor or mediator. Additionally, because none of those overseeing the course had formal training in education, the experiences of the students through their own work to gather information in the project-based learning process seemed to supplement the lack of teacher's training. From the interviews, the students indicated a motivation to learn and continue in engineering education, especially through their experiences with what they reported as authentic learning environments. Finally, the students and teaching assistant indicated that teamwork proved to be one of the more challenging issues of project-based learning. The researchers proposed that training related to teamwork be practiced before and during the projects.

Tseng, Chang, Lou, and Chen's (2011) study of 30 freshmen with engineering background from five, different institutes examined the attitudes of the participants toward STEM before and after a project-based learning activity. Using their STEM knowledge, the students were divided into five groups to finish an electric vehicle. The researchers developed a STEM attitude questionnaire, which had been tested with 100 participants in a pilot study and edited to increase the overall reliability of the questionnaire to Cronbach's $\alpha = .94$. Data from semi-structured interviews were also collected. The results from the questionnaire having items on a five-point Likert scale indicated that the overall student attitude toward STEM was positive and significant before the activity ($M = 3.957$, $SD = .454$, $t(29) = 11.551$, $p < .001$). The results of the pre-test indicated that the students favored technology the most ($M = 3.926$), but the paired-samples t-test showed that significant attitude change occurred toward engineering after the project-based learning activity (M = -.274, *SD* = .573, $t(29) = -2.619$, $p < .05$)—students favored engineering the most.

Jeon, Jarrett, and Ghim's (2014) study of a second-year engineering course explored whether motivational strategies from the Attention-Relevance-Confidence-Satisfaction (ARCS) model could be combined with project-based learning. Researchers worked with 48 students to see how they would respond to project-based learning in their course. The last third of the course was devoted to project-based activities, in which students worked in small groups to study, orient, identify, define, implement, report, and evaluate their work. Because the students grouped themselves according to their gender, gender was also considered in the study. The results showed that the ARCS motivational strategies could be incorporated with project-based learning in order to improve the project-based learning in engineering courses. However, the researchers suggested that more studies be conducted related to motivation and project-based research and gender because the hypothesis has been that women work better in small groups than a large lecture environment (Amelink & Creamer, 2010; Johnson, 2007; Lou, Liu, Shih, Chuang, & Tseng, 2011), but the results of the study did not indicate so. In all four scales males were significantly more motivated than the females—attention (M_{males} = 3.35, SD_{males} = .47, $M_{females}$ = 2.99, $SD_{females}$ = .41, $t(46) = 2.795$, $p = .008$), relevance (M_{males} = 3.72, SD_{males} = .38, $M_{females}$ = 3.39, $SD_{females}$ = .35, $t(46) = 3.147$, $p = .003$), confidence (M_{males} = 3.15, SD_{males} = .42, $M_{females}$ = 2.67, $SD_{females}$ = .47, $t(46) = 3.733$, $p = .001$), and satisfaction (M_{males} = 3.47, SD_{males} = .62, $M_{females}$ = 2.96, $SD_{females}$ = .52, $t(46) = 2.951$, $p = .005$).

Blended Learning and Active Learning in Undergraduate Science Education

Before addressing the possible affordances of BL on AL, general operational definitions of BL for the study first need to be made. Following the definitions is a section describing how BL may contribute to AL in undergraduate science education, particularly the large introductory science courses.

Definitions of Blended Learning

Blended learning, also known as hybrid learning, has remained an amorphous term due to the rapid evolution for the landscape of BL (Graham, 2013). Graham (2012), a leader in the field of BL, has proposed a simple definition: “blended learning systems combine face-to-face instruction with computer-mediated instruction” (p. 4). As BL has been changing, the definitions and classifications of BL have been changing—making the definition of BL a moving target. Norberg, Dziuban, and Moskal (2011) likened BL to a boundary object, an object “plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites….weakly structured in common use….strongly structured in individual site-use” (Star & Griesemer, 1989, p. 393). Despite the challenge to know exactly what BL is, researchers must continue to attempt to demystify and to pinpoint specific characteristics of BL, whether in general or in the context of K-12, higher education, and continuing education. As Garrison and Vaughan (2008) predicted for BL in higher education, “[w]hen blended learning is well understood and implemented, higher education will be transformed in a way not seen since the expansion of higher education in the late 1940s” (p. x). By taking the best of what is being blended—especially, in FTF and online education—a predominant teaching model has the potential to emerge (Watson, 2008).

It has been difficult to separate BL from traditional FTF learning and distance learning because the initial research about BL was an outgrowth from distance learning research (Graham, 2013). Historically, there were the FTF learning experiences and distance learning experiences. Both required the same content knowledge to be shared and to be assessed, but the distance learning experiences did not have the FTF component between the instructor and student throughout the knowledge-sharing and assessment (Holden & Westfall, 2009). With the development of technologies like computers, CD-ROM, and, most importantly, the Internet, *e-learning* emerged—creating a bridge that expedited communication and made teaching and learning more personable in both synchronous and asynchronous learning opportunities despite physical distance between the instructor and student (Holden & Westfall, 2009). E-learning, including online learning, was apparent not only in distance learning but also in traditional FTF learning environments, thereby birthing *blended learning* (Masie, 2006). Since then, BL has evolved based on need (Norberg, Dziuban, & Moskal, 2011), which Graham (2006) argues can be found at the activity level, course level, program level, and institutional level. Figure 2-3 provides examples of how the definitions of BL can be influenced at each of the four levels.

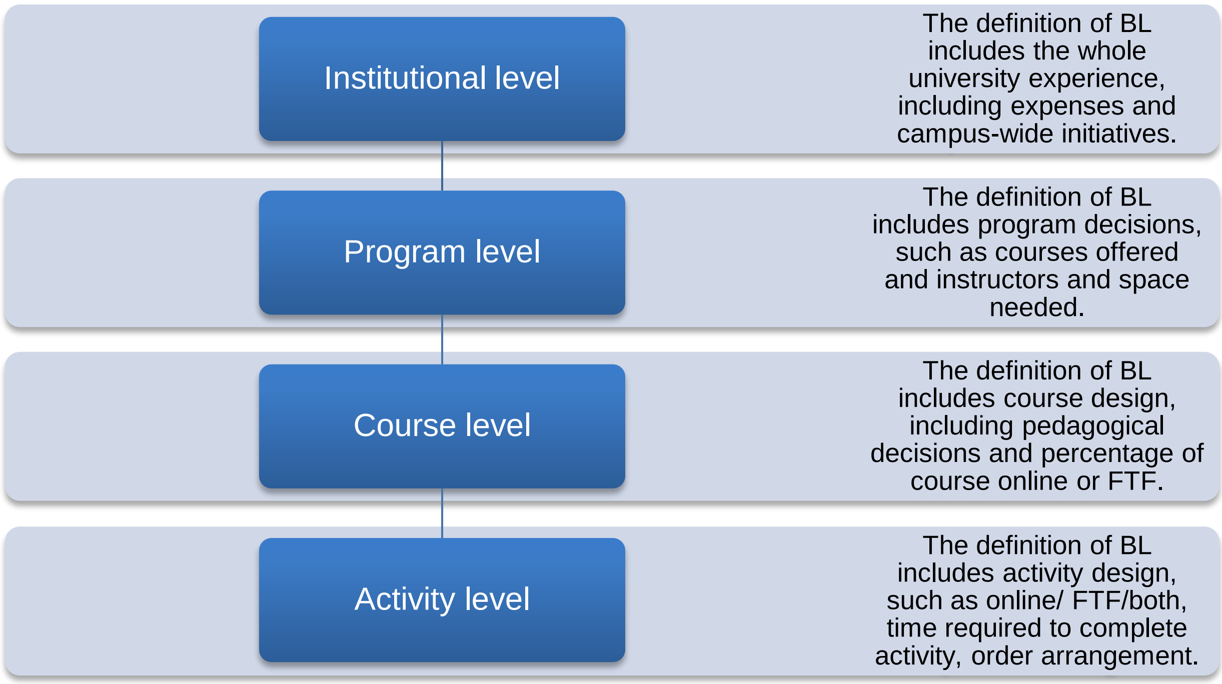

Figure 2-3. Possible influences on the definitions of BL at the hierarchical levels within the university system.

From the top-down, at the highest level of the university the definition of BL may include items like a change in the estimations of costs or campus-wide initiatives for the blending of online and FTF educational practices. At the second level of the program, the definition of BL may include which courses are offered and whether the number of instructors or space used has been affected. The definition of BL at the course level has been highlighted more in research, in which pedagogy and the distribution of FTF and online time have been noted. At the lowest level of the activity the definition of BL may be more practical detailing exactly what students need to do online, FTF, or both and what exact times are expected for activity completion. The order of the determined activities may be incorporated into the BL definition as well.

Specific definitions for BL may be diverse depending on the level using BL or on the persons designing the BL environment (Graham, 2012; Hofmann, 2006; Sharpe et al., 2006). As BL became more popular, Graham, Allen, and Ure (2003) took an initial step to crystallize three definitions of BL:

- the combination of instructional modalities or delivery methods (Bersin & Associates, 2003; Orey, 2002a, 2002b; Singh & Reed, 2001; Thomson, 2002);
- the combination of instructional methods (Driscoll, 2002; House, 2002; Rossett, 2002); and
- the combination of online and FTF instruction (Reay, 2001; Rooney, 2003; Sands, 2002; Ward & LaBranche, 2003; Young, 2002).

Discussion using the first two definitions would be unfruitful, in that most of today's educational practices combine instructional modalities and instructional methods—making most forms of education BL according to those definitions (Graham, 2013). Thus, the focus should be on the third definition, which, Graham (2012) emphasizes, brings together two historically separate teaching and learning models (i.e., traditional FTF and distributed learning systems) and advocates for the use of computer-based technologies in the educational process.

Adding to the discussion of what BL is according to the third definition, Chew, Turner, and Jones (2010) share a useful collection of definitions upon their literature review as seen in Table 2-1. More up-to-date definitions have been added to the list.

Table 2-1. Definitions of blended learning

Researchers	Definitions of BL
Thorne (2003)	Integration of technological advances available through online learning and the best practices of interaction and participation through traditional learning

Table 2-1. Continued

Researchers	Definitions of BL
Littlejohn and Pegler (2007)	Combination of online learning with other approaches (e.g., FTF instruction) or the mixture of media in online learning
Sloan-Consortium (Vignare, 2007)	(1) Combination of online with FTF instruction according to selected pedagogy, and (2) trade off between FTF time and online activities
Allan (2007)	Use of online tools (e.g., chats, discussion groups, online tests) to support a FTF course
Graham, Woodfield, and Harrison (2013)	Combination of FTF and online learning with the reduction of class time
Wang, Han, and Yang (2014)	A system that is complex, adaptive, dynamic, self-organizing, and co-evolving with multimodal environments when bringing together FTF learning and technology-mediated instruction

Using the definitions as reference, the study defines BL as a combination of online instruction with the use of online tools (e.g., chats, discussion groups, and online tests) and FTF instruction being driven by a selected pedagogy—in this case, AL.

Four Dimensions of Interaction in Blended Learning

The basic definitions of BL set a foundation of what BL is; however, there remains the question of how exactly is BL implemented. Depending on the purpose and practitioners, BL may have a different appearance from class to class. For example, the Sloan Consortium has defined BL as having 30% to 79% of learning be online and the rest be delivered via FTF instruction or other non web-based methods, including paper textbooks (Allen, Seaman, & Garrett, 2007). However, when considering BL for the purposes of the study, the researcher reviewed how BL is practiced across the four dimensions of space, time, fidelity, and humanness (Graham, 2006). Figure 2-4 shows each of the four dimensions.

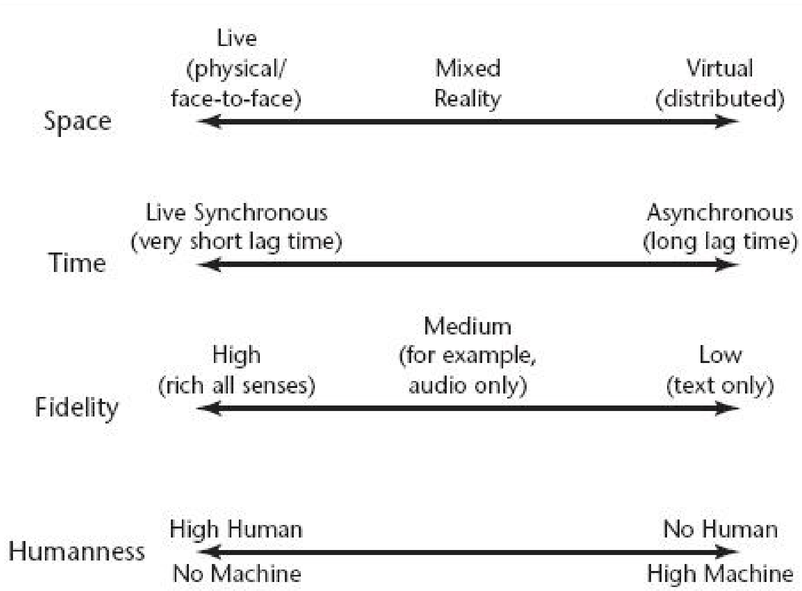

Figure 2-4. Four dimensions of interaction in FTF and online environments (image used with author's permission; Graham, 2006).

Each dimension has its own continuum, and a BL environment may find itself at a different point on a continuum for each dimension. For example, a BL environment may be more on the right side of the continuum with more time spent online and less FTF time in class, but have high fidelity and high humanness because the instructors and students use high fidelity technology like a virtually simulated environment and spend much time communicating with each other through chatting and online conferencing.

Space

The first dimension is space, as the location for learning being FTF or online. Although it is easy to think of space as being exclusive—either instructors or students are meeting FTF or online—the argument for the future space may be that the computer-mediated learning environment may simultaneously occur in the FTF environment as seen in Figure 2-5 (Graham, 2006).

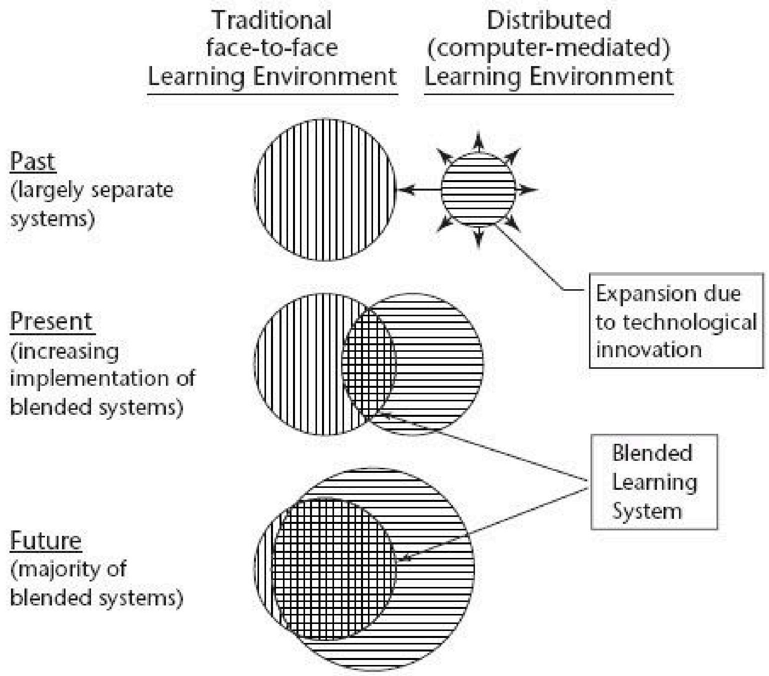

Figure 2-5. Graham's (2006) diagram of the progressive convergence of traditional FTF and distributed learning environments allowing the development of BL systems (used with permission from author).

Rather than focusing on distributed (computer-mediated) learning environments, this study analyzes BL implemented using online learning environments such as learning management systems (LMSs)—due to the evolution of technology, computer or mobile, to be conveniently connected to the Internet at all times and the current context of undergraduate science education. The reality is that more than 60% of undergraduate science courses at the large research institute where this study was conducted use Canvas™, an online LMS, to support F2F, online, and BL. Graham also discusses the blending of learning using online rather than distributed learning environments in his 2013 work in the *Handbook of Distance Education*.

Traditionally, an LMS like Canvas™ has been designed primarily to support online learning, so the repurposing and the use of the affordances of online LMSs for effective blending with traditional FTF learning environments is up to each individual instructor due to the lack of specific tools designed specifically for a blended environment (Graham, 2006). Most educational technologies have been developed to support a fully online distance education environment (e.g., online LMSs, flash card, quiz applications) or teaching in the FTF classroom to support FTF interactions (e.g., clickers and Microsoft® PowerPoint presentations). However, with more development in technology for the BL environment, the prediction is that the blend between FTF and online learning environments will be more prolific (Graham, 2006) and the design of technologies for blended learning will be more deliberate and strategic. Although there will remain the different FTF and online environments, use of BL will increase, purely FTF learning traditions will be minimal, and purely online learning will remain about the same due to its convenience supporting personal online learning outside of required class time. Computer simulations, including virtual simulations, have been one example that changes the thinking of space in relation to BL (Baepler et al., 2014). More about virtual simulations is discussed in the Fidelity section.

Time

Often presented together with arguments related to the dimension of space is the dimension of time. There has been the argument that, when defining BL, there should be the mention that seat time be decreased (Mayadas & Picciano, 2007; Picciano, 2009; Vaughan, 2007). For example, Picciano (2009) has proposed that "a portion (institutionally defined) of face-to-face time [should be] replaced by online activity" (p.

10). Although in-class time may be decreased, the argument is that FTF time will continue to exist. Baepler and associates' (2014) study using a posttest-only nonequivalent groups design compared a control group in which 350 students in spring 2012 attended a traditional lecture chemistry course in theater-style seating for 50 minutes three times a week to the experimental group in fall 2012 and another experimental group in spring 2013, which both consisted of three subgroups of about 117 students each and attended class for 50 minutes only once a week due to a BL format. In the study not only was there a change in the amount of class time the students received, but the classroom environment for the experimental group was also an active learning classroom (ALC) in which students sat around circular tables and access to technology ports to more easily share information via their laptops. For the assessment of the groups, the American Chemistry Society (ACS) exam was used, as well as a validated 32-item survey instrument asking the students about their perceptions of how the classroom environment encouraged engagement, learning in general, and flexibility for different learning approaches. As a result, even with the reduction of 66% of the class time, the second experimental group significantly outperformed the control group on the ACS exam ($M_{control}$ = 65.80, $SD_{control}$ = 14.10, $M_{experimental\ 1}$ = 68.87, $SD_{experimental\ 1}$ = 12.73, $t(577) = 2.744$, $p < .01$). When the control group was compared to the second experimental group, there was no significant difference in the performance on the ACS exam ($M_{control}$ = 65.80, $SD_{control}$ = 14.10, $M_{experimental\ 2}$ = 66.36, $SD_{experimental\ 2}$ = 13.64, $t(618) = .86$, $p > .05$). In regard to the student's perception of the affordances of learning within a BL format and in an ALC, there were significant differences in that the students indicated that their learning experiences had more engagement, flexibility, and confidence and higher student outcomes ($p < .001$). Students also noted that their learning experience was enriched ($p < .05$).

Fidelity

Whether for the purpose of substituting once required FTF time or adding to the FTF or online learning environment, Graham (2006) proposes that the level of fidelity contributes to a realistic BL environment—one that engages the senses. Examples include the common use of text (low fidelity), audio (medium fidelity), and technology rich to all senses such as video or virtual simulations (high fidelity). Tun, Alinier, Tang, and Kneebone (2015) propose that fidelity should not be considered how complete and faithful a simulated environment is to reality, rather it should be an accurate representation of real-world cues and stimuli—the fidelity of an environment depends on the students' perceptions of reality. In Lehmann, Bosse, Simon, Nikendei, and Huwendiek's (2013) study in medical education, a field with a growing interest in the fidelity of simulations, the students' learning experiences with medium and high fidelity virtual patients (video virtual patients and mannequin virtual patient, respectively) were evaluated with questionnaires and semi-structured interviews. Out of the 310 students who interacted with the virtual patients, 179 students answered the questionnaire about their BL experiences with items on a five-point Likert scale. The students scored the overall experience as 4.3 ± 0.7. They rated the teaching presence throughout the whole experience as 4.1 ± 0.9, cognitive preparation before the laboratory as 4.2 ± 0.7, and the social environment of the in-person laboratory as 4.3 ± 0.7. They agreed there was a high learning effect by rating the experiences as 4.0 ± 0.7. From the semi-structured interviews, students reported they received good preparation to assist real patients due to the ability to work with the medium and high fidelity virtual patients at their own pace at home. The students were also more likely to focus on areas of weakness with the affordances of time and space that BL allowed.

Humanness

Humanness is characterized as to how dependent learning is on another human being, or how much there is the presence of a human versus machine. Humanness differs from space in that it is focused on interactions or what many call the “human touch.” The researcher argues that, for example, a student may be in a large lecture hall with peers and the instructor but experience little humanness because there is very little or no interaction with the instructor or other students. In an online environment, humanness would rely on technologies including computer-supported collaboration, discussion forums, social media, and chatting. Blended learning affords the humanness—the person-to-person interaction—that is more difficult to achieve in purely online learning (Stein & Graham, 2014).

The two more prominent interactions are student-to-student and instructor-to-student. Regarding the former, Clark and James (2012) conducted a qualitative study of the BL experiences within an introductory undergraduate geoscience course. The researchers held three focus groups of six to eight students in the group, totaling for 20 participants. For the FTF component, lecture was the primary practice, and students did not interact much with each other but only minimally with the instructor. The students were encouraged to interact in online discussions; some students were able to answer questions from other students, but a challenge occurred when responses would not be posted in a timely way. Students felt less stressed asking questions to their peers, and questions could also be asked anonymously which further lessened anxiety in asking questions. However, the students indicated their disdain for other students who would review the discussions but were "lurkers" who did not contribute.

In relation to the interactions between instructors and students, Hung and Chou (2015) developed and conducted a confirmatory factor analysis with the instrument—the Online Instructor Role and Behavior Scale (OIRBS). The purpose of the instrument, having scores on a five-point Likert scale, was to examine students' perceptions of instructors' roles in BL and online learning environments by examining five areas in which instructors function: course designer and organizer, discussion facilitator, social supporter, technology facilitator, and assessment designer. Participating in the study were 750 undergraduate students enrolled in either of two BL ecology courses. The results of a multivariate, repeated one-way ANOVA showed that Hottelling's Trace was significant (F = 39.698, p <.001). Thus, a post hoc was carried out showing that students in the BL environment perceived the instructors in the following order: course designer and organizer, discussion facilitator, technology facilitator and assessment designer (the mean scores were the same), and social supporter.

Establishing the definition of BL along the four dimensions contributed to the definition of BL affordances as the students' understanding and use of BL components. For example, the instructor-identified BL component of in-class clicker questions was not merely a component in itself, but the students' use of the in-class clickers to answer questions encouraged discussion among the students. The immediate function of the in-class clicker questions was to provide instructors feedback about students' comprehension; however, for the students, the in-class clicker questions not only contributed to monitoring their own learning but also built small learning communities and supported scientific discussions.

Understanding Blended Learning for Active Learning in Undergraduate Science Courses

The coupling of the pedagogical practices of AL and the possible support provided by BL creates a conceptual framework, which may be referred to as Blended Learning for Active Learning, or BL4AL, wherein BL enables or constrains AL as the catalyst for learning among the undergraduate science courses.

Active learning at its inception has been contrasted to the purely instructor-teach-and-student-listen model; it has been defined as students actively engaging in the learning process through reading, writing, discussing, and being engaged in problem solving, all the while using higher-order thinking skills of analysis, synthesis, and evaluation (Bonwell & Eison, 1991). Although Mayer (2004) makes the case that lower behavioral and cognitive activities do not jeopardize learning, AL comes from a place where students are empowered to take charge of their learning with the support of the instructor (Bonwell & Eison, 1991).

In the context of undergraduate science education, the development toward BL4AL is still in the early stages. Due to the efficiency associated with "covering the content," in-class lectures and laboratory times are still common practice, especially in the large introductory-level science courses that are the gateway to other science courses in a student's major (Kober, 2014). A BL science course may simply include the addition of online components or technological interventions to FTF instruction or out-of-class work; at times seat time is replaced with the online components or technological interventions as well. Baepler and associates (2014) compared students in purely in-person undergraduate chemistry courses to students in BL courses with online content delivery and in-person participation in an AL classroom. The online components were merely optional online lectures, computer simulations within the FTF environment, and clicker interactions during class. In Gonzalez' (2014) study comparing a traditional FTF class, a class infusing lecture and laboratory time, and a BL class, the BL class was a blend of FTF time and online activities, which included online lectures and video clips. Overall, 31 hours of required FTF time were reduced in the BL treatment group. In attempts to define BL, Picciano (2009) proposed a spectrum of BL with various examples of BL (see Figure 2-6).

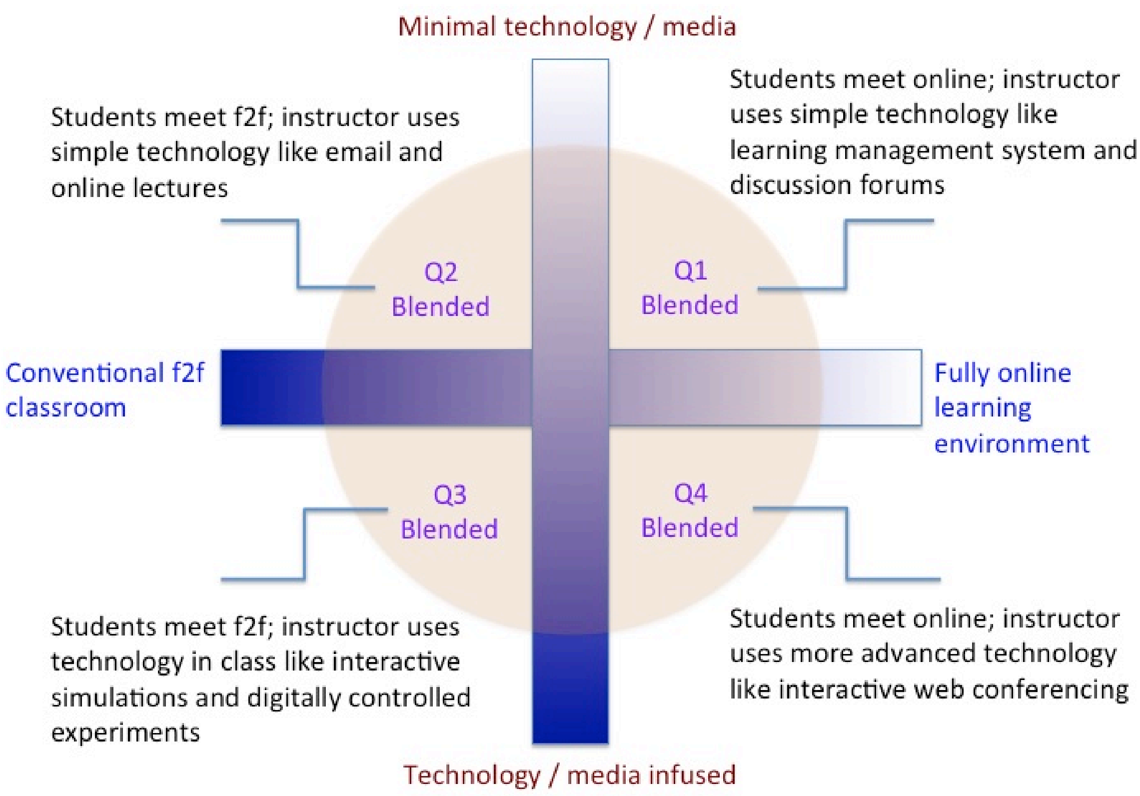

Figure 2-6. Researcher's representation of Picciano's (2009) broad conceptualization of blended learning.

Undergraduate science education tends to fall in quadrant 2 (Q2), where BL is closer to a conventional FTF classroom and there is technology/media. In the BL environment, students attend class and instructors tend to use such as emails and recorded online lectures.

Understanding Persistence as an Important Science Learning Outcome

The data collected contributed to a more defined BL4AL conceptual framework. Although the BL4AL instrument is the key component of the quantitative aspect of the study, it is, nevertheless, also the overarching concept that is being studied—possible effects of BL affordances for AL in relation to the students' perceptions of learning experience and their persistence in the introductory science courses.

In addition to the AL and BL frameworks presented, the BL4AL framework incorporated what Graham and associates' (2013) have termed Persistence Framework for science retention, which expresses the relationship between AL, science education, and student persistence (see Figure 2-7).

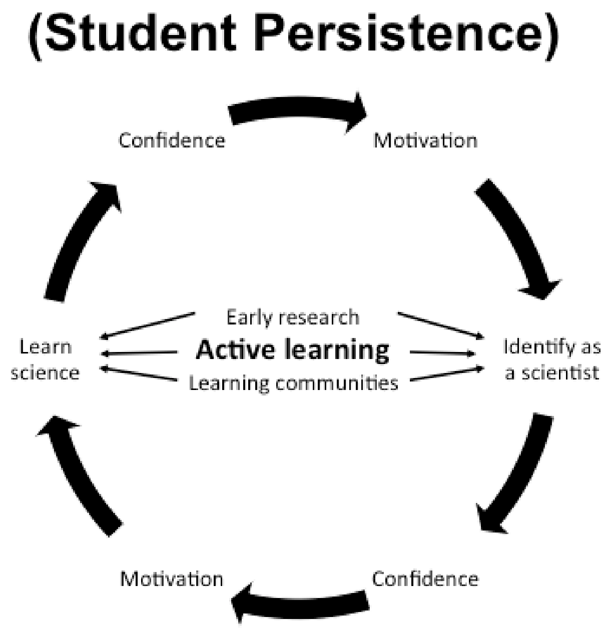

Figure 2-7. Graham and associates' (2013) Persistence Framework for science retention.

In order to encourage student persistence, there is a cyclical relationship with motivation, confidence, learning science, identifying as a scientist, early research opportunities for students, learning communities, and AL. Within the framework, persistence is not mentioned explicitly in relationship to the different components because the whole process constitutes persistence. Motivation is defined as a driver of student engagement, and confidence is defined as the student's perception of self-efficacy (Dweck, 1986). With confidence and motivation, students engage in learning more about science. In addition to learning science, for student persistence in science education the students need to feel like scientists in their studies, and approaches like AL and its manifestation of inquiry-based learning have encouraged students to identify as scientists and to undergo steps of inquiry for discovery (Crippen & Archambault, 2012). Thus, active learning, research experiences earlier in the students' university experience, and learning communities feed into the students' learning of science and experiences of being a scientist. For the purposes of the research, the effect of AL on the student persistence cycle is the influential component particularly examined.

Conceptual Framework Informing the Study

For the purposes of the study, BL was considered at the course level, and defined as not only the blend of FTF and online space for learning purposes but also the blend of synchronous and asynchronous (related to time), of text-only content and content rich to all senses (fidelity), and of high human interaction with little technology and low human interaction with more technology (humanness). Along with the operational definition of BL, Figure 2-8 illustrates the conceptual framework for how the affordances of BL relate to AL and, ultimately, student persistence. The framework BL4AL drove the design of the study, including the design of the BL4AL instrument administered for quantitative data collection. The model represents the study’s purpose to examine the affordances of BL for AL for student persistence. The top left side of the framework shows a modified version of Graham’s (2006) four dimensions of interaction in FTF and online environments.

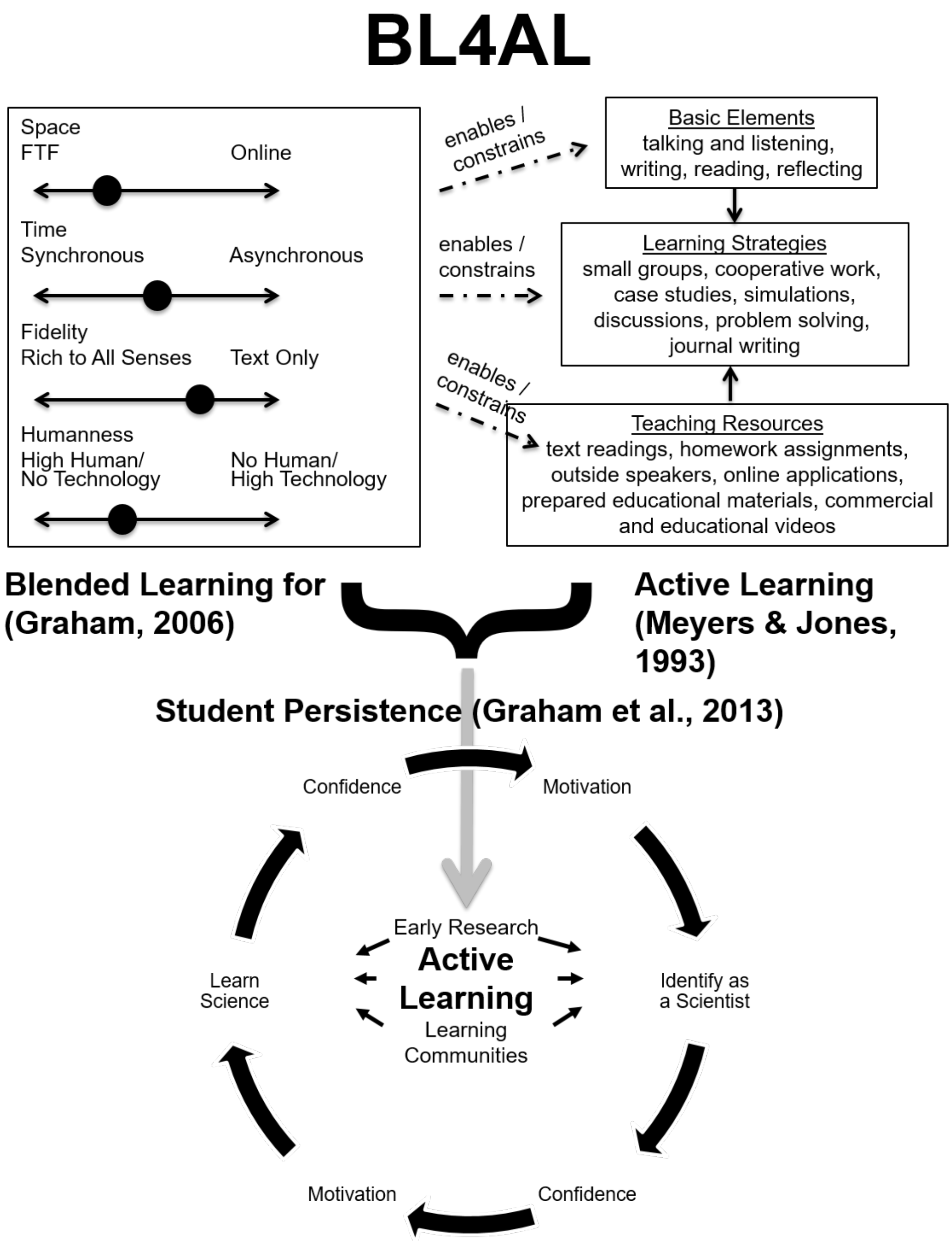

Figure 2-8. Conceptual framework of blended learning in undergraduate science education for active learning practices.

Additionally, the researcher has marked on each dimensional continuum where undergraduate science education falls based on the reviewed literature. Similar to where it lands in Picciano's (2009) broad conceptualization of BL (see Figure 2-6), BL in undergraduate science education continues to focus on learning in the FTF environment, is split between synchronous and asynchronous learning, uses more text-based media, and depends more on the human touch rather than on technology. Based on the present status of BL in undergraduate science education, the affordances of BL may enable and constrain AL in the courses, as seen with the dashed arrows. The idea that BL affordances can enable or constrain AL stems from the argument that media affordances can enable or constrain pedagogical methods (Kozma, 1991, 1994; Graham, 2013). Although the affordances may not be direct causal factors, they may "represent classes of pedagogies distinct enough to enable [or constrain] differences to be measured in meta-analyses where researchers have not yet identified the actual causal factors" (Graham, 2013, p. 340). The arrows are not solid in order to allow for other forces (e.g., university bureaucracy and finances) to possibly enable or constrain AL. On the right side of the framework is Meyers and Jones' (1993) proposed AL structure. Although the framework was proposed in 1993, it provides a practical yet succinct presentation of AL that remains appropriate for the present discussion. The basic elements and teaching resources feed into the creation of learning strategies, while the affordances of BL affects all three areas constituting AL. Rather than having a linear relationship, the relationship of BL and AL becomes a more organic one—in which BL relies on AL for its existence and helps to shape what AL ultimately appears like in its learning strategies. For example, the prevalence of the use of clickers in the classroom for immediate problem solving or discussion teaching leads back to the AL element of reflecting, which is influenced by the four characteristics of BL in undergraduate science education.

Based off Graham and associates’ (2013) Persistence Framework for science retention, the AL in the framework is the AL constrained or enabled by BL, which then affects student persistence as seen through the students' motivation, confidence, learning of science, and identity as a scientist. This conceptual framework guided the research design, including the creation of the interview protocols for instructors and students, respectively, and the determination of items in the BL4AL instrument.

CHAPTER 3
METHODOLOGY

Introduction

Based on the BL4AL conceptual framework, this study was designed to address the following research questions:

- How do BL affordances for AL practices manifest in introductory science courses?
- According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?

An embedded mixed-methods design was employed in this study—a survey nested within a case study design using the research methods of interviews, observations, review of documentations. Although case study design has often been considered to be a qualitative design, case studies can include quantitative data that enrich the knowledge of the case (Yin, 2014). Thus, the case study methodology guided the overall data collection and analysis; more specifically, due to the *how* research questions, an explanatory case study was conducted, in which its “purpose is to explain how or why some condition came to be” (Yin, 2014, p. 238). The results of the data collected and analyzed through the explanatory case study led to an overall interpretation of the effects of BL on AL in large introductory science courses for the purpose of student persistence.

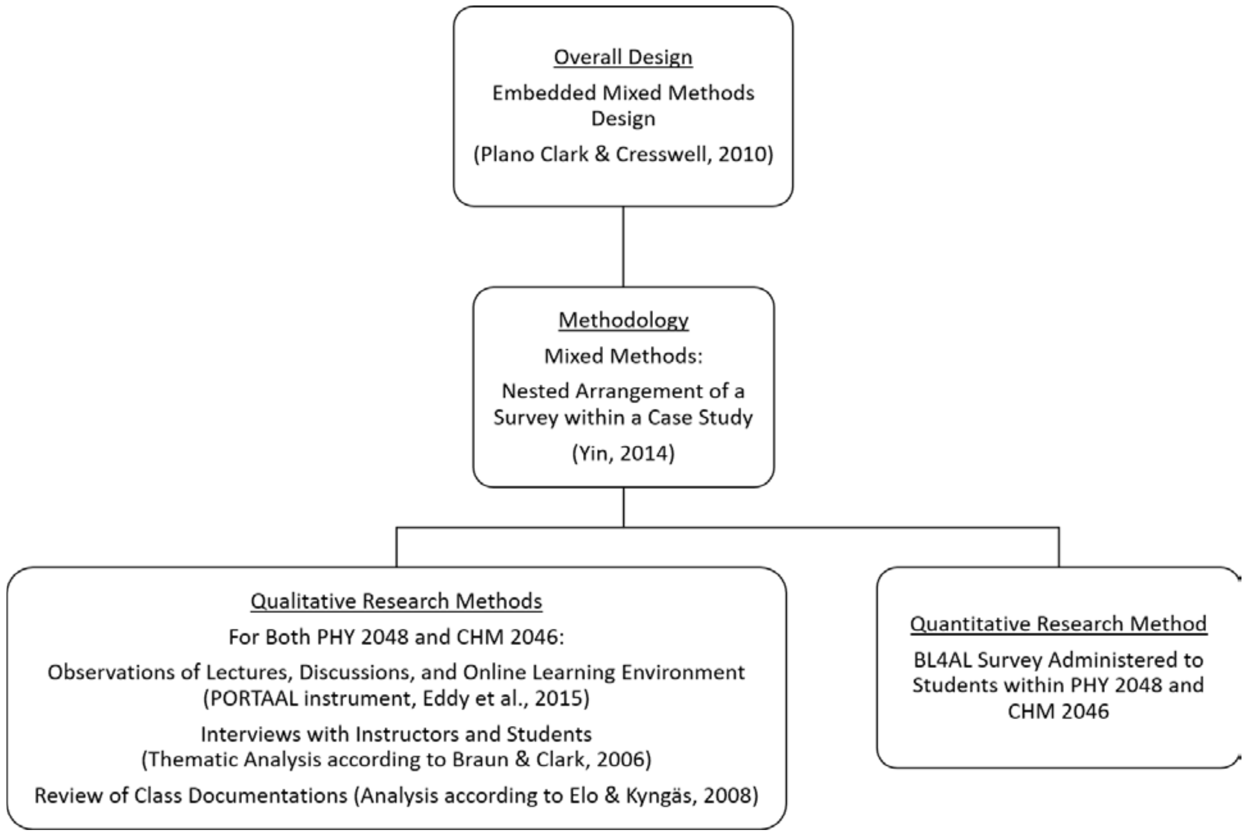

Figure 3-1. Organizational chart of study's research design.

Due to the investigative nature of the study to explain *how* BL related to AL and student persistence in these two cases, the case study was the most appropriate methodology to use (Yin, 2014). In response to the prejudice that case studies lack rigor, the researcher followed systematized, research-based ways to collect and to analyze multiple sources of data for triangulation (Braun & Clark, 2006; Eddy et al, 2015; Elo & Kyngäs, 2008; Johnson & McClure, 2004; Yin, 2014). To address the argument that case studies cannot allow scientific generalization, the purpose of the research is not to generalize results to the population but to focus on the "particularization" of the cases so that they would be examined in detail first and their uniqueness compared to others second (Stake, 1995, p. 8). The transferability of the findings is considered—whether the findings from the context within the study transfer to another context without losing the meaning and inferences from the study (Houghton, Casey, Shaw, & Murphy, 2013; Leininger, 1994). At this point in time, academic research cannot separate how BL affordances for AL influence student persistence from the context in which the BL, AL, and students' persisting occurs. Thus, the need to consider the phenomenon in an up-close and in-depth manner may not produce generalizeable results, but it may become a stepping stone for future studies to pinpoint areas that can be generalized (Yin, 2012).

Multiple-Case Study

Yin (2014) describes multiple cases being examined within one major study as a "multiple-case study." In fields like political science and medicine, a single case study and a multiple-case study, or comparative study, have their differences in design and purpose and have been pitted against as to which one is more favorable (Eckstein, 2000). One major difference between using a single case and using the multiple case is that the evidence from the multiple-case study may often result in more compelling and more robust findings, especially through cross-case analysis (Yin, 2014). Despite the differences between the applications of the two designs, the study follows Yin's (2014) recommendations for the basic case study framework, which is essentially the same for a single-case study and a multiple-case study (see Figure 3-2): develop a theory, select the case(s), design data collection protocol, conduct the case study (or studies), and write the individual case report(s).

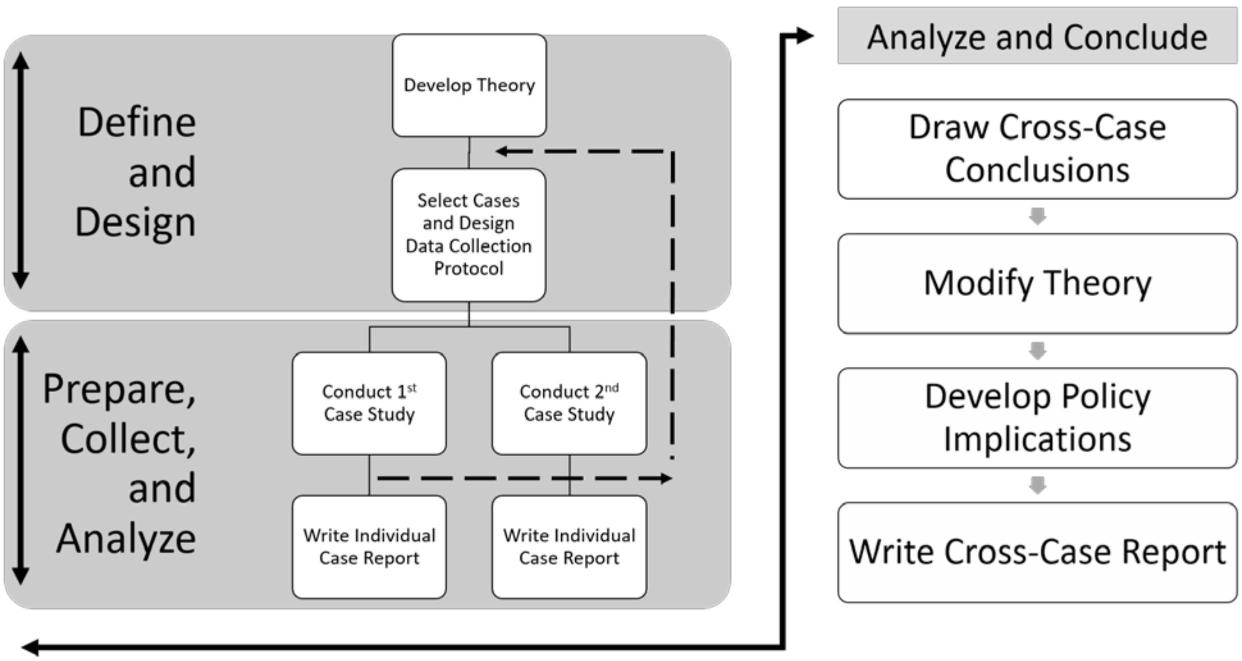

Figure 3-2. Case study methodology based on Yin's (2014) recommendations.

Thus, the study was a holistic multiple-case study, in which data were first collected and analyzed for each individual case, then underwent cross-case analysis.

In the past, some researchers had mistakenly followed sampling logic for the multiple-case study, considering multiple subjects to be the multiple cases—similar to designing a within-experiment design instead of a cross-experiment design (Yin, 2014). The multiple-case design should follow replication instead of sampling logic, indicating that the "major insight is to consider multiple cases as one would consider multiple experiments" (Yin, 2014, p. 57). Thus, in order to properly set up a multiple-case study, a replication framework based on the study's conceptual framework was created for case selection. The selected cases met the following criteria: incorporated BL affordances, encouraged AL practices, and were introductory science courses. Upon data collection, a report was written for each case and afterward a cross-case analysis was prepared. According to one of the top case study researchers, Yin (2014) argues that case study research design consists of (a) the research question(s), (b) its propositions (if any), (c) the unit of analysis, (d) the logic linking propositions to the data, and (e) criteria for interpreting findings.

(a) Research Questions

Driving the study were the following research questions:

- How do BL affordances for AL practices manifest in introductory science courses?
- According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?

Drafting the questions initiated the explanatory investigation for the advancement of theory related to the affordances of BL on AL for student persistence.

(b) Propositions

Propositions are similar to hypotheses that determine the scope of a study; they reflect the study's theory and provide a direction to relevant evidence in relation to the theory (Yin, 2014). Based on the research questions and the conceptual framework, two propositions drove the case study research:

- Blended learning affordances enable or constrain AL (the proposition attempts to establish that BL influences AL; Baepler et al., 2014; Graham, 2006; Kober, 2014; Meyers & Jones, 1993).
- The relationship between BL and AL encourages or discourages student persistence through building motivation, confidence, a learning of science, and an identity as a scientist (the proposition indicates BL and AL can positively or negatively influence student persistence; Crippen & Archambault, 2012; Graham et al., 2013).

(c) Units of Analysis

The courses PHY 2048: Physics 1 with Calculus and CHM 2046: General Chemistry 2 at a large research institute in the American Southeast were the units of analysis. Participants included the instructors and the students. At the beginning of the study, the researcher discovered that PHY 2048 consisted of three mini-courses. Each mini-course was overseen by an instructor, and although the mini-courses followed the syllabus and an instructor could consult with the other instructors, each instructor ran a mini-course autonomously from each other. The mini-courses were created so that an instructor could devote more time to research and have the responsibility of overseeing a mini-course for about five weeks. In order to make the results more comparable because the role of the instructor highly influences the implementation of BL, the study focused on the instructor's and students' experiences within the second of the mini-courses. Although CHM 2046 was a semester-long course, the researcher decided that the two courses were sufficiently similar to continue a comparison. In general, the courses were first chosen because they were mandatory beginning-level science courses that students took to advance in degrees such as biology, chemistry, medicine, and engineering. Thus, they can be described as gatekeeper STEM courses that are important because they are prerequisite courses for multiple STEM degrees. Science gatekeeper courses were the focus in this study primarily because these courses are where students are introduced to the discipline at the university level and where their expectations, self-efficacy, and motivation to persist are either reinforced or ruined (Cromley et al., 2015; Graham et al., 2013; Kober, 2014). In addition, to stay within the scope of the study, only courses with BL formats were considered. The BL characteristics were exhibited through the lecture types, the variety of technology used, the expectations of time within and outside the course, and the amount of FTF and online human interaction expected in the course.

The scope of the study extends to all student experiences related to the course. Beginning with the syllabus and other documentations, the BL affordances recommended and supported by the instructors constitute the course (e.g., FTF lectures, online homework, office hours). Upon the interviews with the students, identified BL affordances relating to the course (e.g., out-of-class work with friends, online resources, and tutoring services) also constituted the course—the reason being that, in order for a more all-encompassing understanding of the relationship with BL affordances and AL, all identified affordances were included and considered in the study.

(d) Logic Linking Propositions to Data

Before conducting the data analysis, Yin (2014) recommends that the consideration of how propositions link to data becomes a guide for collecting relevant data and a foundation for the data analysis. Two of the recommended analytic techniques used were pattern matching (Trochim, 1989) and cross-case synthesis (Ericksen & Dyer, 2004; Hooks, 1990). In pattern matching the process "always involves an attempt to link two patterns where one is a theoretical pattern and one is the other is an observed or operational one" (Trochim, 1989, p. 356). Following the strategy during the data analysis, the researcher identified repeated information within the data and linked it to the propositions of how BL influences AL and how the BL-AL relationship influences student persistence. After identifying patterns within each case and synthesizing the cases, the researcher conducted cross-case synthesis. The synthesis requires a comparison of the merged information, examining similarities, differences, and patterns between the cases; furthermore, the ultimate summary of the comparison yields its own propositions to be compared to the propositions made before the study (Ericksen & Dyer, 2004).

(e) Criteria Used to Interpret Findings

A discussion of the criteria, particularly for the qualitative data analysis, must be conducted before the analysis so that possible rival explanations of findings are identified, thereby strengthening the findings (Yin, 2014). Yin (2000) identifies two major types of rivals that may be what is actually occurring versus the proposed main explanation to the observed: craft rivals and real-world rivals. Craft rivals relate to parallel explanations related to the design and execution of the study, while real-world rivals may be parallel social, external factors that influence the observed. Whether due to the crafting of the study or due to other influences outside of the study, the researcher in Chapter 5: Implications acknowledged possible rival explanations in comparison to the propositions and explanations being made according to the study's framework. Table 3-1 details the rival explanations to be considered and their descriptions.

Table 3-1. Yin's (2000) types of rival explanations

Rival explanation	Description
Craft rival	
Null hypothesis	The observation is the result of chance circumstance only
Threats to validity	E.g., history, maturation, instability, testing, instrumentation, regression, selection, experimental mortality, and selection-maturation interaction
Investigator bias	E.g., "experimenter effect"; reactivity in field research
Real-world rival	
Direct rival	An intervention other than the target intervention accounts for the results
Commingled rival	Other interventions and the target intervention both contributed to the results

Table 3-1. Continued

Rival explanation	Description
Rival theory	A theory different from the original theory explains the results better
Super rival	A force larger than but including the intervention accounts for the results
Societal rival	Social trends, not any particular force or intervention, account for the results

Related to the study, the researcher acknowledged that possible rival explanations would be considered in the data analysis. The possibility of no influence by BL was considered, and investigator bias was addressed in the researcher's positionality statement (Appendix G). Direct rival was the major concern, in that the study attempted to capture the influences of BL, but if components of BL were separated and left to operate on their own merit, they could be at least equally effective. And especially in a study about the three, amorphous areas of BL, AL, and student persistence, the findings and possible implications were also compared to the last three rival explanations of rival theory, super rival, and societal rival; another theory may explain the results better than the study's theory, a force larger than BL but includes BL may influences AL and eventually student persistence, and the social trend advocating BL, AL, and STEM education may influence the results.

Data Collection

Data collection methods were a combination of traditionally qualitative research methods, i.e., interviews, observations, review of documents, and a traditionally quantitative research method, i.e., survey (Plano Clark & Creswell, 2010). Data from the qualitative research were triangulated to increase trustworthiness, and the survey instrument based on previously validated instruments was also validated and its data tested for reliability. Within the context of each case, the methods addressed the research questions:

- How do BL affordances for AL practices manifest in introductory science courses?
- According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?

Each subsection below explains which question(s) the method contributed to answering. An audit trail, synonymous with decision trail, was also kept as a chronological document that notes the reasoning behind major decisions made throughout the study (see a one-page sample of the audit trail for physics case study in Appendix H; Koch, 2006; Sandelowski, 1986). In order to support the qualitative research's trustworthiness, or rigor, an audit trail was created so that another researcher can follow a document "discussing explicitly decisions taken about the theoretical, methodological and analytic choices throughout the study" (Koch, 2006, p. 92).

Interviews

Data collected from semi-structured interviews with instructors and students answered both research questions. At the beginning of the spring 2017 semester, the researcher interviewed the lead instructor in PHY 2048 and CHM 2046 to determine what BL affordances were utilized in the course (see Appendix A for the protocol to be used in interviews with instructors). Following the BL4AL framework, questions constituted the categories of: within the context of FTF learning and online learning in the course, AL components, and persistence-focused questions (see Figure 2-8 for the BL4AL framework).

The researcher interviewed six students per course. For PHY 2048, the announcement for student volunteers was made in the announcement section on the course's website. For CHM 2046, the researcher made an announcement before a lecture. Students were told that their participation would assist in academic research and earn them a $20 giftcard. More than six students volunteered to participate in each course. In attempts to obtain multiple and diverse student perspectives, in each course the researcher chose to interview two students who were low performing (having a C or lower letter grade in the course at the time when volunteers were requested), two students who were average performing (having a letter grade from a C+ to a B), and two students who were higher performing (having a letter grade from a B+ and A+). In PHY 2048 the instructor assisted in sorting which student volunteers belonged to which category; in CHM 2046, the students informed the researcher what their course grade was at the time (with IRB approval). Questions for the student participants were similar to the questions asked of the instructors (see Appendix A and Appendix B), also capturing the context of FTF learning and online learning in the course, AL components, and student persistence. Both sets of protocols were crafted with questions that addressed the major components of the study's framework: Graham's (2006) four dimensions of BL, Meyers and Jones' (1993) proposed AL structure, and Graham and associates' (2013) student persistence framework.

The interviews were transcribed and underwent thematic analysis. Rounds of coding were conducted to see what themes surfaced—a code being defined as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (Saldaña, 2015, p. 4). Following Braun and Clark's (2006) recommendations for thematic analysis, in the initial stage of coding the researcher became familiar with the data through reading and rereading the data and writing down initial notes. In order to begin identifying and coding themes, initial codes were made as comments on the transcripts in Microsoft® Word and Dropbox™; the comments targeted words and lines that related to BL, AL, and student persistence. To address the first research question focused on how BL affordances influenced AL, the instructors' interviews were first coded to see what affordances arose during the design of the courses. Initial codes that arose from the data included specific BL affordances such as "homework system's not sophisticated," "purpose of the discussion section = human interaction," and "instructor made videos to help students and influenced him to change his teaching style." The consideration of affordances assisted with the pursuit to understanding how the activities were being taken advantage of within BL environments supporting AL, for "when affordances are taken advantage of, the user knows what to do just by looking: no picture, label, or instruction needed" (Norman, 1988, p. 9). Thus, once the initial codes were made after coding the instructor's interviews, the students' interviews were then coded to see how the instructor's design compared to the students' experiences. The interviews of students who performed above average were coded first because their responses may align more similarly with the instructor's since they are doing well in the course. The last group to have their interviews coded was the group performing below average—the reasoning being that the group of students would have the most different perspectives about BL on AL because they have the lowest grades. Examples of codes included "demo only partially helpful," "clickers good with basic stuff," and "still feel nervous about exams." Students' responses were considered positive when they indicated that the affordances enabled them to practice AL according to Meyer and Jones' (1993) recommendations of the blending of basic elements to learning (e.g., talking and listening, reading, writing, and reflecting) and teaching resources into learning strategies. When students indicated that the affordances became a constraint to the AL process, the responses were considered to be negative ones.

In order to address the second research question about student persistence, the same coding process occurred in that instructors' interviews were first coded to note their considerations of the students' persistence in the forms of motivation, confidence, science learning, and identification as a scientist; then the students' interviews were coded. Because instructors and students were directly asked about their perspectives related to the four areas related to student persistence, their responses were coded according to why they positively or negatively felt about their own motivation, confidence, science learning, and identification as a scientist—examples include "motivated to pass exam and to earn good grade" and "less confident due to not achieving expected exam grade."

Once the initial codes were made, a second round of coding began that consisted of looking for themes. In the process Braun and Clark (2006) recommend that potential themes answer the research question(s) and are supported by the overall story of the data, and final naming conventions of the themes be informative and engaging, possibly short quotes being representative of the theme. Themes emerged from lengthier explanations from the students instead of a mere acknowledgement that the students did or did not use the BL affordance. Based on the study's conceptual framework, the themes relating to the first research question related to the affordances themselves (e.g., demonstrations, clickers, class videos) and the relationship between BL and AL (e.g., how the affordance enabled AL in discussion or for the online homework experiences). For example, concerning discussions, themes were "discussion class offers homework support" and "discussion class is only a place to take the quiz." In response to the second research question, multiple themes emerged from the initial coding. For example, with persistence category of identifying as a scientist, an emerging theme was "being a scientist demands a 'keep-going' attitude," a student's belief that more in-depth training to be a scientist can be obtained if students continue in the sciences and can enroll in smaller classes beyond the introductory science courses. In Chapter 4 the individual case studies report the results from the initial codes, and themes are presented with the interview data. The cross-case analysis compares and contrasts the emerging themes. Chapter 5 discusses the implications of the themes.

Review of Documentations

The review of documentations answered the first question about the manifestations of BL affordances for AL. The term "documentations" was chosen instead of "artifacts," as Yin (2014) distinguishes documentations as written evidence like emails, announcements, and administrative documents, while he defines artifacts as evidence that is produced like a technological device, a work of art, or an instrument. For each case, the researcher reviewed the PHY 2048 course website that acted as the course's syllabus, the electronic copy of the CHM 2046 course syllabus, and online course announcements.

Elo and Kyngäs's (2008) recommendations for content analysis were chosen and followed for the analysis process:

- In the phase of preparation, extensive reviewing the data is the first step before selecting the unit of analysis;
- The organizing phase includes open coding and creating categories; the codes are then grouped under higher-order headings. (The resulting organization assists in writing descriptions related to the research questions, and a conceptual map reports the final results.)

Because of the online nature of all the documentations to be more like webpages (except the CHM 2046 course syllabus that was a .pdf), the researcher noted on a spreadsheet the review of the documentation with the open codes and to what in the documentation the open code referenced. Example of codes included in “Course Overview,” “students supposed to attend lecture,” and “be proactive and ask questions.” The open codes were then grouped under higher-order headings that related to each of the research questions. For example, “Constraints to AL” and “Enablements to AL” were headings to the grouped open codes. A conceptual map is reported in Chapter 4.

Observations

Within the online learning environment, the researcher needed to distinguish between documentations and observations of the online learning environment because text constituted most of the online environment. Documentations were considered to be unidirectional, meaning that the instructor was able to share information with students, but students did not have the direct opportunity to act or to give feedback. Observations were made of interactions among students or between students and the instructor within the online environment.

When observing in a class, the researcher used Eddy and associates’ (2015) observation tool Practical Observation Rubric To Assess Active Learning (PORTAAL) (see Table 3-1). Although there are a number of observation tools available, PORTAAL was particularly designed to capture research-supported components to AL occurrences in undergraduate STEM classrooms. As a rubric, the tool attempts to make observations quantifiable based on the number of AL-related occurrences within the classroom. For the use of the instrument there were supplementary materials including a training manual (Converse, Eddy, & Wenderoth, 2014), an observation log, and a conversion chart that provides more explanation with the observed number of AL-related occurrences. The instrument of four dimensions with 21 items has been validated (Eddy et al., 2015), and each dimension is supported by literature:

3. Practice—students practicing the information that they will be tested on (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Epstein, Lazarus, Calvano, & Matthews, 2002; Preszler, Dawe, Shuster, & Shuster, 2007; Jensen, McDaniel, Woodard, & Kummer, 2014; Thomas & McDaniel, 2007),

4. Logic development—students exercising critical thinking to understand concepts rather than just answer lower-level questions (Jensen et al. 2014; Nielsen, Hansen-Nygård, & Stay, 2012; Schworm & Renkl, 2006; Smith, Wood, Krauter, & Knight, 2011; Turpen & Finkelstein, 2010),

5. Accountability—raising the incentive for students to participate through graded assignments, peer work, and/or cold calling in class (Eddy, Brownell, & Wenderoth, 2014; Freeman, O'Conner, Parks, Cunningham, Hurley, Haak, Dirks, & Wenderoth, 2007; Hoekstra & Mollborn, 2012; James & Willoughby, 2011), and

6. Reducing apprehension—calming students to participate (Bell & Kozlowski, 2008; Dallimore, Hertenstein, & Platt, 2010; Ellis, 2004; Fritschner, 2000; Good, Rattan, & Dweck, 2012; Goodboy & Myers, 2008).

Table 3-2 shows how the four PORTAAL dimensions of best practice appear in activity development and activity implementation phases of introduction, student engagement, and/or debrief. The activity development is the set up to the activity, whereas the three phases occur during activity implementation—the argument being that each activity should have an introduction, a time for student engagement, and a debrief (Converse et al., 2014).

Table 3-2. Eddy and associates' (2015) four dimensions of best practice to implement classroom activities

PORTAAL Dimensions	Activity Development	Activity Phase: Introduction	Activity Phase: Student Engagement	Activity Phase: Debrief
Practice	P1. Allocate class time for practice. P2. Use questions/problems that align with exams. P3. Include questions requiring the use of prior knowledge.			P4. Have students explain their answers in front of whole class so instructor/students can provide immediate, respectful feedback.
Logic Development	L1. Use questions/problems that require critical thinking.	L2. Remind students to explain their answers.	L3. Give students explicit time to answer alone before any other form of engagement. L4. Have students discuss in groups before whole class discussion/debrief. L5. Do not reveal clicker histogram or provide hints between iterations of engagement.	L6. Call on students to explain their logic. L7. Be sure the logic behind the right answer is explained. L8. Frequently explain why the alternative answers are wrong.
Accountability	A1. Make activity participation worth course points (ideally for participation not correctness).		A2. Avoid relying on volunteers instead employ small groups work. A3. For whole class discussions, call on many students via cold or random call.	A3. For whole class discussions, call on many students via cold or random call.

Table 3-2. Continued

PORTAAL Dimensions	Activity Development	Activity Phase: Introduction	Activity Phase: Student Engagement	Activity Phase: Debrief
Reducing Apprehension		R5a. Remind students that mistakes are a necessary part of the learning process.	R1. Use random call to spread participation in discussions. R2/R6. Praise class effort. R3. Make sure students know their contributions to large discussions are appreciated. R4. Avoid demeaning student answers.	R2/R3. Make sure students know their contributions to debriefs are appreciated. R5b. Emphasize how wrong answers contribute to discussion and are valued. R6. Praise students for hard work and effort rather than correctness / intelligence.

An example of the observation log (rubric) that was used to note AL practices in the class is found in Appendix C. Due to the lack of observation protocols for the online portion of a BL class, for each course the researcher used at least the dimensions in PORTAAL to assess the online environment. Any section that was unidirectional, in which information was being shared with students with no direct way for students to give a response or receive feedback, was considered a documentation. The results of the online observations are presented in Chapter 4: Findings.

In the analysis of the PORTAAL results, using the conversion chart, the element observed in the classroom was converted to a numerical summary measure (see Appendix D for the conversion chart of observations to PORTAAL scores). The results were then interpreted according to Graham's (2006) BL dimensions of fidelity, space, time, and humanness and Meyers and Jones' (1993) AL characteristics. Table 3-3 shows the mapping of how the noted best practices in PORTAAL relate to the components in the conceptual framework. Although the practices may relate to more than one component, they have been organized to the component they best support. For example, “L4. Have students discuss in groups before whole class discussion/debrief” could be applicable to all three aspects of the conceptual framework; however, the nature of the statement indicates the focus is on human interactions rather than AL in general or encouraging persistence among students. Two items have been added to the best practices by the researcher not only to enrich the suggested best practices for AL but also to add examples of how fidelity and space can support AL. The items discuss having students practice working with real-world simulations (fidelity) and having students practice inside class and online (space).

The same rubric was used to assess the online environment. However, rather than converting the observations to percentage of activities, the presence or absence of evidence for an item within a dimension was noted and explained in Chapter 4. For example, there was evidence of “L1. Frequent opportunities to practice higher order skills in class” because students had access to online practice exams and could practice those at any time and ask questions within the Canvas™ discussions.

Table 3-3. Mapping Eddy and associates' (2015) four dimensions of best practice in PORTAAL to proposed study's conceptual framework

Four Dimensions of BL (Graham, 2006)	AL Structure (Meyers & Jones, 1993)	Persistence Framework (Graham et al., 2013)
P1. Allocate class time for practice. [Time] P4. Have students explain their answers in front of whole class so instructor/students can provide immediate feedback. [Humanness] Researcher Added. Have student practice working with real-world simulations. [Fidelity] Researcher Added. Have students practice inside class and online. [Space]	P2. Use questions/problems that align with exams. [Teaching resources] P3. Include questions requiring the use of prior knowledge. [Teaching resources]	
L4. Have students discuss in groups before whole class discussion/debrief. [Humanness]	L1. Use questions/problems that require critical thinking. [Teaching resources] L2. Remind students to explain their answers. [Basic elements] L3. Give students explicit time to answer alone before any other form of engagement. [Basic elements] L5. Do not reveal clicker histogram or provide hints between iterations of engagement. [Learning strategies] L6. Call on students to explain their logic. [Basic elements]	L7. Be sure the logic behind the right answer is explained. [Learning science] L8. Frequently explain why the alternative answers are wrong. [Learning science]
A1. Make activity participation worth course points (ideally for participation not correctness). [Space]	A2. Avoid relying on volunteers instead employ small groups work. [Learning strategies] A3. For whole class discussions, call on many students via cold or random call. [Basic elements]	

Table 3-3. Continued

Four Dimensions of BL (Graham, 2006)	AL Structure (Meyers & Jones, 1993)	Persistence Framework (Graham et al., 2013)
	R1. Use random call to spread participation in discussions. [Learning strategies]	R2/R3. Make sure students know their contributions to debriefs are appreciated. [Identifying as a scientist] R2/R6. Praise class effort. [Confidence] R3. Make sure students know their contributions to large discussions are appreciated. [Identifying as a scientist] R4. Avoid demeaning student answers. [Confidence] R5. Remind students that mistakes are a necessary part of the learning process. Emphasize how wrong answers contribute to discussion and are valued. [Motivation] R6. Praise students for hard work and effort rather than correctness / intelligence. [Confidence]

Survey

Survey data addressed both research questions about BL affordances for AL and about BL affordances for AL for student persistence. Despite the association of traditional qualitative research methods to case study research, quantitative research methods like the survey have also contributed to the case study (Yin, 2014). Yin (2012) likens the explanatory case study to the use of factor theories, in that both investigate the correlation of a dependent variable with a number of independent variables. The purpose of the survey used for the study, Blended Learning for Active Learning (BL4AL), was to capture students' perceptions regarding the effects of BL affordances for AL for their own persistence in the science courses, as seen in their motivation confidence, science learning, and identification as a scientist. For PHY 2048, a Qualtrics© version of the survey was administered toward the end of the mini-course with the instructor; for CHM 2046, the survey was administered through Qualtrics© toward the end of the semester.

Development of BL4AL

Because there is not a single previously validated measure of the perceived effects of BL on the AL with a focus on student persistence, the survey used in this study was based on the following: the researcher's proposed conceptual framework; Eddy and associates' (2015) four dimensions of best practices for AL as seen in PORTAAL (see Table 3-1); and Johnson and McClure's (2004) version of the Constructivist Learning Environment Survey (CLES), also called CLES 2(20) (see Appendix E).

The PORTAAL was designed as a rubric to be used when observing AL within classes. In Eddy and associates' (2015) study, before administering the survey, the content validity of the instrument was based on extensive research literature (see the Observations section of this chapter). Seven biology education researchers with recent publications (within two years from the time of invitation to review the instrument) confirmed the items to be valid: 100% agreement on 10 of the 18 observations (total number of observations was 21 but three were consolidated into one for the review), seven had 86% agreement, and one had 71% agreement. Because observers were paired in the study and the data were interval data, interobserver reliability was determined using the two-way agreement, single-measures interclass correlation coefficient, or ICC (McGraw & Wong, 1996). All resulting ICCs were > 0.8, thereby in the "excellent" range (Cicchetti, 1994).

Originating with Taylor and Fraser (1991), the CLES was a survey administered to instructors and students in order to capture their perspectives on constructivist learning environments. Since the first study, the instrument has been validated in multiple studies (Aldridge, Fraser, Taylor, & Chen, 2000; Aydin, Box, Sungur, & Çetín, 2012; Johnson & McClure, 2004; Lee & Fraser, 2001; Taylor & Fraser, 1991; Taylor, Fraser, & Fisher, 1997). Regarding Johnson and McClure's (2004) version of CLES, the survey in the study was first administered to 290 elementary-level and secondary-level science teachers in order to ascertain the teacher's perspectives on the personal relevance, uncertainty, critical voice, shared control, and student negotiation within a class (it was argued that the scores on the scales would contribute to the assessment of the constructivist learning environment within a classroom). The data underwent an exploratory factor analysis (EFA), and reported values of the Cronbach alpha reliability coefficient for the different scales ranged from .80 to .91. However, Johnson and McClure reviewed the participant comments and results of the EFA and reliability analysis, and decided to revise the CLES to have fewer redundant, confusing items—producing the CLES 2(20), maintaining the five scales but limiting each scale to four items. The revised forms for instructor perception and student perception were then administered to instructors and students, respectively, in two other iterations. Because there were more students per instructor in the iterations, alpha coefficients were only obtained for the student perception survey. In the first iteration, values for the different scales ranged from .72 to .89, and in the second, values ranged from .76 to .90. The factorial structure for the CLES 2(20) ultimately consisted of four items loaded onto five factors (i.e., personal relevance, uncertainty, critical voice, shared control, and student negotiation).

Following the PORTAAL and CLES2(20), BL4AL also had a factorial structure, in which four major factors were identified to indicate student persistence according to Graham and associates' (2013) framework: student motivation (SM), student confidence (SC), science learning (SL), and identification as a scientist (IS). Under each factor were eight items written to learn more about the student's perceptions of BL affordances for AL that related to that particular factor – for a total of 32 items. Each factor had eight items so that each dimension of BL (i.e., space, time, fidelity, and humanness) would be represented by two items (see Appendix F). The items were based off the items within the PORTAAL and CLES2(20) that captured student motivation, student confidence, science learning, and identification as a scientist. Table 3-4 shows how the BL4AL items related to the PORTAAL and CLES items; some PORTAAL and CLES items influenced more than one BL4AL item.

Table 3-4. Items in BL4AL and their influential items in the respective sources

BL4AL Item	Source: Influential Item
SM1. To consider the social impact that science can make.	CLES: New learning relates to experiences or questions about the world inside and outside of school.
SM2. To have more of a desire to solve a scientific question for answers on my own.	CLES: Students let me know if they need more/less time to complete an activity.
SM3. To look for other learning resources that my instructor has not suggested.	CLES: Students help me plan what they are going to learn.
SM4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.	CLES: Students let me know if they need more/less time to complete an activity.

Table 3-4. Continued

BL4AL Item	Source: Influential Item
SM5. To be interested in learning more about science outside of class requirements.	CLES: Students learn about the world inside and outside of school.
SM6. To engage in question-asking, responses, or discussions with my instructor and/or peers.	PORTAAL: Have students explain their answers in front of whole class so instructor/students can provide immediate, respectful feedback.
SM7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation.	CLES: Students help me to decide how well they are learning.
SM8. I try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.	CLES: Students help me to decide which activities work best for them.
SC1. To feel comfortable sharing science ideas in class or online.	PORTAAL: Make sure students know their contributions to large discussions are appreciated.
SC2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.	PORTAAL: Have students discuss in groups before whole class discussion/debrief.
SC3. To use more than one sense to learn new science information.	PORTAAL: Give students explicit time to answer alone before any other form of engagement. PORTAAL: Frequently explain why the alternative answers are wrong.
SC4. To notice in my daily life through different senses what I learned in my science class.	CLES: Students help me to decide which activities work best for them.
SC5. To feel confident in finding resources to help my learning.	CLES: Students learn about the world inside and outside of school.
SC6. To feel comfortable enough to take risks and to make possible mistakes.	PORTAAL: Remind students that mistakes are a necessary part of the learning process. Emphasize how wrong answers contribute to discussion and are valued. CLES: Students feel safe questioning what or how they are being taught.
SC7. To feel confident when taking science quizzes or tests.	PORTAAL: Use questions/problems that require critical thinking.
SC8. To effectively manage my time to learn the materials for my science class.	CLES: Students learn how science is a part of their inside- and outside-of-school lives.
SL1. To take time to consider the effects of scientific practices and discoveries.	PORTAAL: Make sure students know their contributions to debriefs are appreciated.
SL2. To share what I am learning with my instructor or peers.	PORTAAL: Include questions requiring the use of prior knowledge.
SL3. To take new information and build upon prior science knowledge.	CLES: Students help me to decide which activities work best for them.
SL4. To can obtain the necessary information or equipment for science learning.	CLES: Students learn about the world inside and outside of school.

Table 3-4. Continued

BL4AL Item	Source: Influential Item
SL5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.	CLES: Students learn that science is a way to raise questions and seek answers.
SL6. To raise questions and seek answers when learning about science.	PORTAAL: Use questions/problems that require critical thinking. PORTAAL: Be sure the logic behind the right answer is explained.
SL7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).	CLES: Students learn about the world inside and outside of school.
SL8. To have adequate space to take the necessary steps to solve a scientific question.	PORTAAL: Give students explicit time to answer alone before any other form of engagement.
IS1. To use more than one of my senses to understand present scientific theory.	CLES: Students learn interesting things about the world inside and outside of school.
IS2. To have adequate time to journal or write down what I have learned.	PORTAAL: Give students explicit time to answer alone before any other form of engagement.
IS3. To hear or read about what today's scientists are practicing.	CLES: Students learn that scientific explanations have changed over time.
IS4. To access science experts who have projects that I can join if I asked.	CLES: Students learn how science is a part of their inside- and outside-of-school lives.
IS5. To take the time to review and challenge the present scientific theory I have learned.	CLES: I feel students learn better when they are allowed to question what or how they are being taught.
IS6. To have the necessary space to work with others to solve scientific problems.	PORTAAL: Avoid relying on volunteers instead employ small groups work.
IS7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).	PORTAAL: Make sure students know their contributions to debriefs are appreciated.
IS8. To test science knowledge through discussions, assignments, or any other class activity.	PORTAAL: Use questions/problems that require critical thinking.

Because the study's definition of BL is not only the blend of online and FTF learning and followed Graham's (2006) definition of BL being a blend of space, time, fidelity, and humanness, using the terms "traditional" and "nontraditional" class experiences was a better way to capture BL instead of the commonly considered blending of online and FTF education. At the beginning of each survey section, students were reminded that examples of traditional class experiences included the use of pen and paper, in-class lectures and discussions, physical textbook readings, and paper exams and that examples of nontraditional class experiences included online apps, online communication, online activities, virtual simulations, online assignments, and clickers. When considering traditional class experiences, students rated on one five-point Likert scale from 1 Strongly Disagree to 5 Strongly Agree how much they agreed with the 32 statements divided into the four categories, eight statements per category. They then rated on a second five-point Likert scale from Strongly Disagree to Strongly Agree how much they agreed with the same statements in relation to their nontraditional class experiences.

Although each item supported one of the four factors related to student persistence, each statement in the survey was also written to capture a dimension of BL (i.e., space, time, fidelity, and humanness; Graham, 2006) and a component of the AL structure (i.e., basic elements, teaching resources, and learning strategies; Meyers & Jones, 1993). For example, the statement “I take as much time as I need to solve a scientific question for an answer” expressed the BL dimension of time in which the student should be afforded more liberty in respect to time when solving a scientific question, and the AL basic element of reflecting was being practiced. Each BL dimension was represented by two statements, and each AL structure component was represented at least twice. The goal of writing the statements with BL and AL characteristics was to strengthen the study of students’ perceptions about BL for AL on student persistence. Appendix F includes a breakdown of BL and AL components for each item; the references included with all the categories and items were removed in the copy shared with instructors and students for validation and in the survey given to students in the participating courses.

Student demographics

For PHY 2048, with a 30.2% response rate, 228 students responded to BL4AL with at least one response in the eight sections of student motivation-traditional learning methods, student motivation-nontraditional learning methods, student confidence-traditional learning methods, student confidence-nontraditional learning methods, science learning-traditional learning methods, science learning-nontraditional learning methods, and identification as a scientist-traditional learning methods, and identification as a scientist-nontraditional learning methods. For CHM 2046, 302 students responded with at least one response in each of the eight sections, resulting in a 43.1% response rate. Table 3-5 consists of the demographics of respondents for both courses. In response to gender identification, students were able to identify their gender as male, female, transgender female, transgender male, and gender variant / non-conforming. The ones shown in the table are the ones that were noted in the responses. The majority of physics students were male (61.1%), while the majority of chemistry students were female (66.6%). Students were also able to identify as multi-racial for their ethnicity—about half the students in each course identified as being white.

Table 3-5. Student demographics in PHY 2048 and CHM 2046

	PHY 2048 (n=228)		CHM 2046 (n=302)	
Characteristics	n	%	n	%
Year				
Freshman	185	81.1	211	69.9
Sophomore	40	17.5	72	23.8
Junior	3	1.3	18	6.0
Senior	0	0.0	1	0.3
Gender				
Male	139	61.0	100	33.1
Female	87	38.2	201	66.6
Transgender female	1	0.4	0	0.0
Gender variant / non-conforming	1	0.4	1	0.3
Ethnicity				
Asian or Pacific Islander	35	15.4	56	18.5
Black	9	4.0	10	3.4
Hispanic	33	14.4	40	13.2
White	120	52.6	159	52.6
Multi-racial	31	13.6	37	12.3

Validation of BL4AL instrument

Content validity. A draft of the BL4AL instrument was first shared with instructors as subject matter experts for review. The researcher shared an initial draft of the survey with the instructors of the course, as well as all their teaching colleagues in the physics and chemistry departments, respectively. One physics instructor and other chemistry instructor who neither were teaching the courses being studied replied with revisions to make to the items. Their feedback assisted with the content validity of the survey instrument. For example, in response to the original item “I take my time to review the learning resources that I find,” the chemistry instructor commented, “[Y]ou mean check to make sure it is a reputable website?” The researcher clarified the question to read: “[Traditional/nontraditional class experiences have helped me] to take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics."

Face validity. For further feedback, especially with the wording of the items and other items related to face validity, two undergraduate students who were science majors and not associated with the courses reviewed the survey. Their edits were also included in the final version. For example, in response to the original items "I solve science problems in whatever environment I am in," one of the students provided the following feedback: "[T]he ? is just vague, like what do you mean solve science problems, it's not clear what 'science problems' entail." The researcher changed the question to read: "[Traditional/nontraditional class experiences have helped me] to consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation)."

Construct validity. Although the construct validation of BL4AL was not the primary goal within the study, it was a necessary step to ensure that a newly developed instrument properly captured the ambiguous area of students' attitudes about BL affordances for AL for student persistence. A confirmatory factor analysis (CFA) was conducted to determine the correlations between the survey items and latent variables of student motivation, student confidence, science learning, and identifying as a scientist in relation to traditional learning methods and to nontraditional learning methods. A CFA was chosen due to the hypothesis about the number and the nature of factors measured by the instrument (Crocker & Algina, 1986). Within BL4AL, eight items loaded onto each of the four factors constituting student persistence.

The CFA also tested the hypothesis that each of the eight items (see Appendix F) loaded onto a traditional learning method factor or a nontraditional learning method factor. The matrix model equation in Figure 3-3 is a more generalized look of the model. Each observed variable X_{ij} is constituted of a factor loading a_{ij} multiplied by the factor f_{ij} plus the residual term u_{ij}. In the model X_{i1}-X_{i8} load (as seen with a_{11}-a_{81}) onto f_{i1}.

$$\begin{bmatrix} X_{i1} \\ X_{i2} \\ X_{i3} \\ X_{i4} \\ X_{i5} \\ X_{i6} \\ X_{i7} \\ X_{i8} \end{bmatrix} = \begin{bmatrix} a_{11} \\ a_{21} \\ a_{31} \\ a_{41} \\ a_{51} \\ a_{61} \\ a_{71} \\ a_{81} \end{bmatrix} [f_{i1}] + \begin{bmatrix} u_{i1} \\ u_{i2} \\ u_{i3} \\ u_{i4} \\ u_{i5} \\ u_{i6} \\ u_{i7} \\ u_{i8} \end{bmatrix}$$

Figure 3-3. Matrix model equation of hypothesized relationships among each factor and variables.

Based on the model, eight individual CFAs were conducted. A multidimensional CFA with four latent traits was not conducted due to an inadequate sample size and, thus, power for the estimates (Myers, Ahn, & Jin, 2011). Figure 3-4 shows the path diagram of how the eight items loaded onto one factor and how each item has an error score.

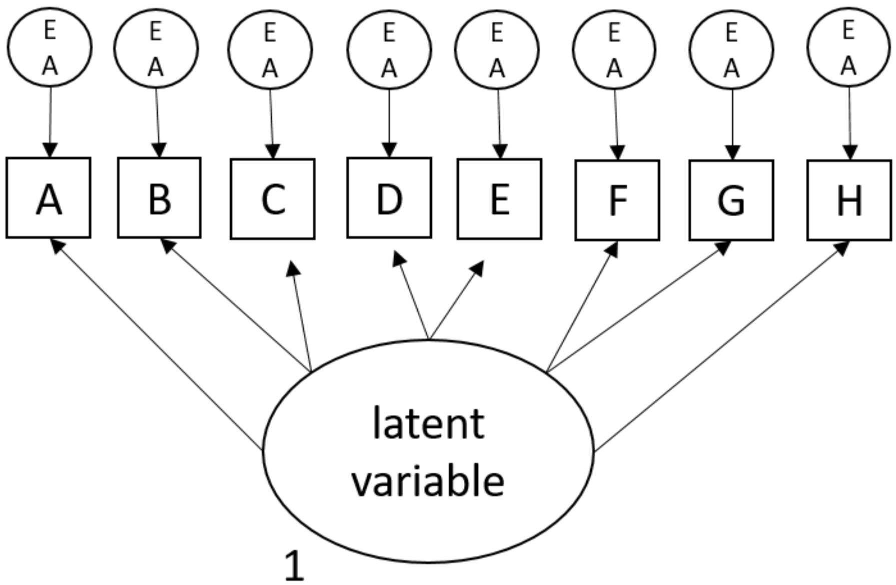

Figure 3-4. Pathway diagram representing the factor structure of each latent variable (e.g., motivation—traditional learning method and identification as a scientist—nontraditional learning method)

In order to give the latent variables a metric, the variance of the latent variable was set to 1 and one of the factor loadings was set to 1 (Brown, 2015). The same path diagram was used for each of the CFAs conducted: motivation—traditional learning method (MTLM), motivation—nontraditional learning method (MNTLM), confidence—traditional learning method (CTLM), confidence—nontraditional learning method (CNTLM), science learning—traditional learning method (SLTLM), science learning—nontraditional learning method (SLNTLM), identification as a scientist—traditional learning method (ISTLM), identification as a scientist—nontraditional learning method (ISNTLM). Appendix I includes the tables showing for each factor the factor loadings and the standard errors for the factor loadings.

As seen in Table 3-5 and Table 3-6, goodness of fit was examined using the chi-square test (X^2), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and the root mean square error of approximation (RMSEA). Although X^2 has been frequently used when evaluating goodness of fit and its values should be cited in reports, arguments against the use of X^2 has been due to its sensitivity to sample size (Hooper, Coughlan, & Mullen, 2008; Hoyle & Panter, 1995). The RMSEA adjusts for sample size (Brown, 2015), CFI also adjusts for issues related to sample size (Gatignon, 2010), and TLI compensates for the effect of model complexity (Hu & Bentler, 1999).

Table 3-6. CFA results summary for the BL4AL subscales in PHY 2048

Subscale	$\hat{\rho}_{X,omega}$	X^2	df	CFI	TLI	RMSEA
MTLM	0.64	53.35*	20	0.87	0.82	0.08
MNTLM	0.79	78.51*	20	0.83	0.76	0.11
CTLM	0.75	99.86*	20	0.74	0.63	0.13
CNTLM	0.79	86.92*	20	0.84	0.77	0.12
SLTLM	0.72	61.54*	20	0.86	0.81	0.09
SLNTLM	0.80	54.23*	20	0.91	0.88	0.09
ISTLM	0.74	57.35*	20	0.85	0.80	0.09
ISNTLM	0.78	29.64	20	0.97	0.95	0.05*

*$p < .05$

Table 3-7. CFA results summary for the BL4AL subscales in CHM 2046

Subscale	$\hat{\rho}_{X,omega}$	X^2	df	CFI	TLI	RMSEA
MTLM	0.88	42.44*	20	0.97	0.95	0.06
MNTLM	0.89	41.00*	20	0.97	0.96	0.06
CTLM	0.89	69.80*	20	0.93	0.90	0.09
CNTLM	0.88	49.74*	20	0.95	0.93	0.07
SLTLM	0.88	29.04	20	0.98	0.98	0.04*
SLNTLM	0.90	27.13	20	0.99	0.99	0.03*
ISTLM	0.85	68.63*	20	0.93	0.90	0.09
ISNTLM	0.89	59.31*	20	0.94	0.92	0.08

*$p < .05$

Based on the results in PHY 2048, the model for ISNTML exhibited goodness of fit with the *p* value of its X^2 being > .05 (Hu & Bentler, 1999). In CHM 2046 the models for SLTLM and SLNTLM exhibited good fit (*p* > .05 for X^2), while the models for MTLM, MNTLM, and CNTLM exhibited mediocre fit (.05 $\leq p \leq$ .07 for X^2) (Hooper et al., 2008; Hu & Bentler, 1999; Steiger, 2007). Whether in PHY 2048 and/or CHM 2046, the rest of the models exhibited acceptable fit for a low stake's study (RMSEA < .10)—with the

CHM 2046 models showing better fit than the ones for PHY 2048 (Browne & Cudeck, 1993; DeCoster, 2009).

Rather than choosing the more popular index of reliability, the Cronbach's coefficient alpha, McDonald's coefficient omega was used as a more suitable index for factor models, particularly due to its ability to index how consistent items measure underlying latent variables (Padilla & Divers, 2013; Zinbarg, Yovel, Revelle, & Li, 2005). It is defined with the equation (Figure 3-5):

$$\hat{\rho}_{X,omega} = \frac{\left(\hat{a}_1 + \ldots + \hat{a}_j\right)^2}{\left(\hat{a}_1 + \ldots + \hat{a}_j\right)^2 + \left(\hat{\sigma}^2_{u_1} + \ldots + \hat{\sigma}^2_{u_j}\right)}$$

Figure 3-5. Equation for coefficient omega.

In the equation the *a* components represent the estimated, standardized factor loadings of each observed variable, and the σ^2_u components are the residual variances for each observed variable (Raykov, 1997). The omega coefficients are reported in Table 3-9 and Table 3-10. As more research is needed regarding the statistical properties of the coefficient omega (Padilla & Divers, 2013), the researcher interpreted all the determined coefficients as being acceptable based on acceptable levels as presented with research related to Cronbach's alpha, i.e., > 0.7 and even > 0.6 for the social sciences (Murphy & Davidshofer, 1988; Nunnally, 1967; Peterson, 1994).

BL4AL Data Analysis

In response to the first research question about the influence of BL affordances for AL, descriptive data were used to describe how the student population in each course responded to the statements describing their attitude about BL in the form of traditional methods and about BL in the form of nontraditional learning methods.

In response to the second research question about student persistence, using SPSS™, the researcher first calculated descriptive statistics related to the surveyed population. Then taking the students' Likert-scale responses, the researcher averaged each student's score within each sub-category under the factors of motivation, confidence, science learning, and identification as a scientist (e.g., motivation—nontraditional learning methods, confidence—traditional learning methods), thereby creating new variables (De Vaus, 2013). Conducting a simultaneous regression in SPSS™, the researcher used the resulting averaged scores as the predictor variables to the outcome variable of the students' indication of whether the respective course motivated them to persist in the sciences. During the cross-case analysis, a sequential regression was conducted. The course subject became a grouping variable in the model, and was tested as a moderator variable in relationship to the dependent variable of student's persistence in the sciences due to the respective course and the other independent variables of the centered average scores among each of the sub-categories under student motivation, student confidence, science learning, and identification as a scientist. The interaction between the independent variables was also examined.

Testing for assumptions of regression. Steps were taken to check the following assumptions of regression: (1) normality, (2) linearity, (3) independence of errors, (4) noncollinearity, and (5) homoscedasticity.

Based on the results from the BL4AL survey administered in PHY 2048, when checking for normality the histograms for the main effects showed normal distribution, and the skewness and kurtosis statistics fell between -1 and 1 (the average of science learning—traditional learning methods and science learning—nontraditional learning methods met the parameters for skewness but kurtosis was 1.06 for both). When checking for linearity, the relationship between the independent variables and the dependent variables proved to be linear. The Durbin-Watson statistic for correlated residuals was 2.25, indicating an acceptable independence of errors as the third assumption tested. The fourth assumption of noncollinearity was met in that all VIF values were less than 10. Finally, homoscedasticity was met—the ratio being 1.50.

The following steps were taken to check the assumptions of regression based on the results from the BL4AL survey administered in CHM 2046. Regarding the assumption of normality, histograms for the main effects showed normal distribution, and their skewness and kurtosis ranged between -1 and 1. The second assumption of linearity was met as the probability plot of the regression standardized residuals followed a linear relationship. To check the third assumption of independence of errors, the Durbin-Watson statistic for correlated residuals was 1.87. All VIF values were below 10 to indicate noncollinearity, and the ratio for variance was below 10, indicating homoscedasticity.

In the cross-case analysis, the histogram for the model exhibited a normal distribution. However, the assumption of linearity was not met with s-shaped curves in the probability plot. The assumption of the independence of errors was met with a Durbin-Watson statistic of 1.99. The assumption of noncollinearity was met with VIF values less than 10, and the assumption of homoscedasticity was met when the interaction variable was removed.

Summary

Table 3-7 is a summary of the alignment of the research questions to data collection and data analysis methods in this study. The results of the data analysis to each case contributed to the cross-case analysis to be detailed in Chapter 4.

Table 3-8. Alignment of research questions, data collection, and data analyses methods to contribute to the cross-case analysis

Research question	Data sources	Data analyses
How do BL affordances for AL practices manifest in introductory science courses?	- Interviews - Documentations (i.e., syllabi, online course content) - Observations	- Thematic analysis of interview data - Content analysis of documentations - Calculation of PORTAAL results (including report of notes taken during observation)

According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?	- Interviews
	- Survey
		- Thematic analysis of interview data
		- Quantitative analysis
		  - Descriptive statistics
		  - Multiple linear regression

CHAPTER 4
FINDINGS

For case study research, four general strategies have been used when analyzing the data: a reliance on theoretical proposition, the working of data from the "ground up," the development of a case description, and the examination of plausible rival explanations (Yin, 2014). Due to the decision to conduct an explanatory case study rather than an exploratory or descriptive one and with the conceptual framework focusing on the relationship between BL, AL, and student persistence, reliance on theoretical proposition became the strategy used for the data analysis. Each tied to a research question, the two major theoretical propositions to the study are: (a) BL affordances enable or constrain AL; (b) the relationship encourages or discourages student persistence. The reported findings explained how the data did or did not support a proposition for each case (Yin, 2014).

Below are the case study reports for PHY 2048 and CHM 2046. The beginning half of each report targets how the data related to the first theoretical proposition that BL affordances constrain or enable AL. The researcher coded the interviews and identified BL affordances influencing AL, as well as identified explanations from the instructors and high-performing, average-performing, and low-performing students about their experiences with BL and AL. In general, although instructors and students spoke about characteristics of BL and AL, they did not use the terms in their vocabulary. With the interview data, themes are reported with the respective BL affordances. The results of the observations and the review of documentations follow the interview data. The second half of the report focuses on how the relationship between BL affordances and AL influenced student persistence. The researcher used data from the interviews and survey results as support for or against the second proposition that the relationship encouraged or discouraged student persistence. After both case studies are reported, results of a cross-case analysis are reported per Yin's (2014) recommendations for a multiple-case study. Within the cross-case analysis, themes from the cases are compared to one another in consideration of the two theoretical propositions.

Case Study Report for PHY 2048: Physics with Calculus 1

The course was a three-credit, 16-week course, which required students to attend one hour of lecture on Mondays, Wednesdays, and Fridays. It was the first in the series of introductory physics courses for physics majors. Differing from its only physics counterpart, the course required students to practice calculus as well. A component of the course was a one-hour-per-week discussion on campus led by a graduate teaching assistant. At the time of the study there were 759 students enrolled in the course and three main instructors who run the course. The instructors met and discussed decisions to be made about the course, but each one took about a four-week block in the course in which he lectured about a set of topics and was mainly responsible for overseeing the course at the time. Thus, although it appeared there was one course, instructors and students indicated the course consisted of three mini-courses that acted autonomously from each other. In order to meet the replication requirement for multiple-case study research that selected cases should be as similar as possible, the researcher decided to review the second instructor's mini-course as a case rather than all three mini-courses. The instructor for the second mini-course was also the lead instructor in the overall course's design. Reviewing the second mini-course required that interviews, the class observations, and the administration of the BL4AL survey be completed before the end of the second mini-course in the semester. Although CHM 2046 was investigated as a full-length course, the researcher decided that both cases were an equal comparison to each other due to the duration of the course not being a component being investigated. The focus was on BL affordances for AL in the courses and the relationship of the affordances for student persistence. As a reminder, “affordances” were not merely activities but the relationship between an object and an individual acting upon the object (Norman, 1999). For example, online discussion forums became affordances when the students interacting with the discussion forums perceived a certain use for the forums—“affordances provide strong clues to the operation of things” (Norman, 1988, p. 9). The particular affordances being examined in the study had a BL nature, according to Graham’s (2006) four dimensions, and were for AL, as defined by Meyers and Jones (1993).

Each mini-course in PHY 2048 was blended in that key components included FTF lectures, in-class clicker questions, online assignments, video lectures, a discussion class, an exam, and the interaction within a learning management system (LMS). The expectations were that students complete 13 homework assignments throughout the semester using their online textbook’s site. Although the assignments were only worth up to five points out of 100 points in the course, the instructor emphasized the online component because the follow-up quizzes during the in-person discussions were based on the same information being covered in the online assignments. Rather than considering the online assignments and in-person quizzes separately, the instructor framed that the online assignments were weighted by the follow-up quizzes. The goal of this design was to reinforce learning and to deter cheating on the online assignments.

Addressing Proposition 1: Blended Learning Affordances Enable or Constrain Active Learning

Instructor's course design decisions as a baseline for the influence of blended learning on active learning

The instructor of the PHY 2048 mini-course being studied was Steve Sanchez. Sanchez was a tenured professor, who devoted most of his time to being a researcher—one achievement being a member on the research team that discovered the Higgs boson (also known as the God particle). The need to attend to his research, as well as the need of the other two instructors to attend to their research, contributed to the division of the course into three mini-courses so that each instructor would be responsible for the course a third of the time. Despite his focus on his own research, Sanchez considered teaching as a research process as well. Although he had been teaching for 19 years—10 of those years teaching introductory physics courses—Sanchez strived to improve his teaching through the use of different types of media. In addition to teaching his FTF courses, he was tasked by the physics department to create online courses:

> I normally talk a lot for the Physics 1 and 2, the individual courses. I changed up a little bit by trying to help with online physics courses. That kept my interest like "Okay, how do I cast this to a new medium?" That brings us to where we are today so now it's done….I have all these videos and that's what's being brought in there and I've—that process of doing that has helped me change my style….What that means is for many years I would present to the students the material, "Here is what is a concept 'momentum.' Here's how it's used. Here's how we calculate this." So somewhat formal. The lecture equivalent of the textbook.

Through the change in his own teaching philosophy as supported by media, Sanchez hoped the changes would make the course better for students: "For me, I know [my teaching has] changed because I will emphasize less the formality of the lectures and give the students what they've always wanted on their student evaluations which is more example problems."

Although he never mentioned the term BL in his description of PHY 2048, he described the affordances in the course, which consisted of BL components based on Graham's (2006) four dimensions for BL. Also, toward the beginning of the interview Sanchez asked the researcher to explain more about an AL environment. In response, the researcher shared it could be an environment "in the physics classroom that would be more engaging into critical thinking. It's not that they're just reading and writing but in the process of reading and writing, there are higher levels of thinking that are being engaged." To which, Sanchez replied, "Yes, it kind of describes what we're doing might be along those lines." He then began to identify BL affordances in the course, including (1) the traditional learning methods of face-to-face (FTF) lecture, in-class demonstrations, office hours, the separately scheduled FTF discussion class, the quiz in the discussion, and the FTF exam and (2) the nontraditional learning methods of emails, in-class clicker questions, the learning management system with a gradebook, the course website, the online course videos, the online textbook, and the online homework.

Sanchez provided more explanation about the roles for the major affordances. In the design of the course the redesign of lectures was key. He shared about the change to having online lecture videos coupled with FTF lectures and how the redesign of the lecture format changed not only the format itself but also the Sanchez's approach to teaching:

> I think taking a step back and looking at a radically different medium video class, online classes, it does force you to say, "Well what are we going to the classroom?" I think trying to target a completely different way of delivering courses does maybe more radically change your perspective on

> how to convey material and that was a good thing at the end. It was a lot of work and not so pleasant at first. Now that you've done all the work you say, "Well now I have more options. I don't have to worry, like, 'Okay I'm not going to put half the class asleep if I spent 20 minutes deriving this equation.'"…We used to say that's in the book, they won't necessarily read that either. But you can tell them now, "There's a video and a book that you can read. We will just assume that this equation has been justified. We already have it."…I'll try to spend more time on what something means rather than how I did get it.

Within the FTF lectures, Sanchez shared that demonstrations helped students to visualize the concepts being taught to them: "If there's a new concept I would try to find an appropriate demonstration. Between you and me, it's as much for them as it is for me, because if you teach yourself over and over again, sometimes a demonstration—well first off, that's a nice, positive lecture. Secondly, it's more interesting—they'll stop looking at their computers." An example of an in-class demonstration was the calculation of the pendulum swing of a hanging bowling ball in order to determine how close Sanchez needed to stand to the ball without being hit by it.

After showing students how to solve problems during lecture, Sanchez indicated that clicker questions in the middle of class tested the students' knowledge and supported discussion among the students:

> Then we have these interactive quicker questions that we put somewhere in the lecture or a couple places in the lecture which allows a break. It asks them a concept, we see if they understood the concept to get the right answer, we discuss it. Like today I was surprised that there was a very easy problem, and I got 57% [of the class to answer] right.... Sometimes we say, "Okay, let's not count that. You guys talk, come up with an answer, and answer it again." And then more will get it right.

Sanchez designed the discussion classes to meet two goals: "One is to [ask] the students, 'What questions do you have?' [They may respond,] 'I don't know how to solve a problem like this.' 'Okay, let's solve a problem like that.' The [teaching assistant] shows them how to solve problems." The second goal was met by the quiz assignment toward the end of the discussion, allowing students to show their understanding of the online homework: “The point of that quiz is to kind of reinforce concepts they did on their homework, and we can discuss it but the homework is online. But for them to demonstrate that they understood the principles we'll ask a question like a homework question not verbatim but very close and have them solve it.” However, the online homework experience did not mirror that of the in-class quiz due to online grading. Rather than seeing if the student understands the process and can partial credit, Sanchez explained, “The way the current homework works is … [if] the answer is 17.05 if [the students] round to 20 they shouldn't round that much so they'll be wrong.” The students were allowed to work together to complete the homework—the instructor’s point of view being “we don’t dominate homework.”

Although Sanchez indicated that all affordances in the course design supported AL for students, he hesitated with the affordances contributed by the publisher of the e-textbook and online homework, WileyPLUS©—pointing out that “this semester is not going well with Wiley. [For example,] we had started with [online issues during] the Super Bowl, up to Monday morning, people working Sunday night, and that system went down…. I'm just not happy with the publisher in this system.” Additionally, Sanchez wanted an online homework system that would allow students to practice visualizing concepts by drawing out concepts rather than only providing an answer: “We are asking more feedback in the sense of ‘give us a drawing, shoot us your explanation’ more than ‘the answer is 17.05 m/s.’” Sanchez considered working with another publisher.

WileyPLUS© and other online components to the course were housed in the Canvas™ LMS. Sanchez considered the LMS a convenient affordance that allowed him to access student grades remotely yet allow the students to see their grades, to maintain his administrative responsibilities through announcements, and to share online content such as documents of old exams for students to practice and lecture notes. He explains:

> I guess that's it….We just make those available, and they can study from those. Our notes, we have our lecture notes because we actually make those online available. We have video lectures, the textbook, other sample tests either on Canvas™ or these past exams that were given. That's the material. Now, they can go online to find other material, but that's I guess what we provide.

Finally, throughout the interview, Sanchez only briefly discussed the FTF exam as a required affordance for students, merely indicating that "the test is Friday night," "we have about a dozen proctors who go in and administer the test," and "we have a two-hour instead of a 50-minute exam." Table 4-1 shows a breakdown of all the BL affordances at least mentioned by Sanchez and whether the BL affordances within the course enabled or constrained AL. According to Graham (2013), the terms "enablement" or "constraint" being used to indicate the relationship affordances can have on pedagogical methods. With each affordance are descriptions of where it lies on the BL continuum (Graham, 2006) and how it contributes to AL (Meyers & Jones, 1993), as indicated in the study's conceptual framework (see Figure 2-8).

Table 4-1. PHY 2048 instructor's vision of the relationship of BL affordances for AL

BL affordance	How BL	How AL	Constraint/ enablement
	Traditional learning method		
FTF lecture	FTF, synchronous, multimedia, high human/new technology	Talking and listening plus room space and knowledgeable speaker feed into taking notes/problem solving	Enablement
In-class demonstrations	FTF, synchronous, multimedia, high human/new technology	Talking and listening plus room space and knowledgeable speaker feed into taking notes/problem solving	Enablement
Office hours	FTF, synchronous, text heavy, high human/low technology	Talking and listening and knowledgeable other feed into discussion	Enablement
FTF discussion class	FTF, synchronous, text only, high human/no new technology	Talking and listening plus room space and homework questions feed into discussion	Enablement
Quiz in discussion	FTF, synchronous, text only, low human/no new technology	Reflecting and quiz assignment feed into problem solving	Enablement
FTF exam	FTF, synchronous, text only, low human/no new technology	Reflecting and exam feed into problem solving	Enablement

Table 4-1. Continued

BL affordance	How BL	How AL	Constraint/ enablement
		Nontraditional learning method	
Emails	Online, asynchronous, text only, high human/new technology	Writing and reading and homework assignments/prepared educational materials feed into discussion/problem solving	Enablement
In-class clicker questions	FTF, synchronous, multimedia, high human/new technology	Reflecting and teaching technology feed into problem solving	Enablement
LMS	Online, asynchronous, multimedia, medium human/high new technology	Reading and reflecting and learning technology feed into discussion	Enablement
Course website	Online, asynchronous, text heavy, no human/new technology	Reading and reflecting and learning technology feed into discussion	Enablement
Online course videos	Online, asynchronous, multimedia, low human/new technology	Listening and reflecting and educational video feed into note taking	Enablement
E-textbook/publisher's site	Online, asynchronous, text only, low human/new technology	Reading and readings only feed into note taking	Constraint
Online homework	Online, asynchronous, text only, low human/new technology	Reflecting and homework assignment feed into problem solving/applying information	Enablement

Perspective of high-performing students on the influence of blended learning affordances for active learning

At the time of the study, students with a letter grade of a B+ or above were considered high-performing students. The first of the two high-performing students, Lucy, retook Physics 1 because she changed her major to medical physics and had taken Physics 1 without calculus. Physics is her minor. The researcher had considered not having her be a participant in the study; however, having taken the course before would not influence her experiences of the BL affordances for AL (as well as her perception of the BL affordances for her own persistence to stay in the sciences). The second of the high-performing students was Stan, a freshman exploratory major in the College of Engineering. As one who always liked STEM courses, Stan inclined to choose chemical engineering or materials science engineering as a major, and took PHY 2048 as a requirement.

When considering the affordances of BL on AL, either Lucy or Stan mentioned an affordance identified by the instructor except none of the students went to the course website or emailed the instructor or a teaching assistant with questions. Like the instructor, Lucy regarded the lectures as an enablement to see and to listen to necessary information: “I sit in the front because I know I feel like I can't, I feel like I can't focus in the back and since sometimes Doctor [Sanchez] is really good about writing big….I can see all the demos and hear everything perfectly fine.” However, Stan noted that the environment did not encourage students to ask questions: “I walk in and there's a lot of people and [the instructor says] that ‘feel free to ask questions.’ But you have the mentality where you don't wanna appear, not dumb, but you don't wanna ask questions just because you might be having a problem with it but nobody else [does].…I feel like all students don't wanna ask questions." Both appreciated the demonstrations, but Lucy recognized there was a possible disconnect between watching a demonstration and connecting that to solving a problem: “I hope that [the demonstrations] will help, but it's nice to see it. How it applies and how a concept is actually—like seeing it happen and being able to do a problem like it is completely different, but it's still, I guess it helps in a way.” *Emerging theme*: The lectures are a spectacle, in which students watch and listen to the instructor present physics concepts.

For more explanation about how to solve physics problems, Lucy shared that the discussion class and office hours enabled her to ask questions:

> I mean like they all like go over like basics in lecture, but I mean it's not enough to get it just from that in discussion. I like to … have two discussions and two lectures instead of three lectures and one discussion. Because obviously, you get—it’s like a smaller environment, less students in the discussion, and more opportunity to ask questions. Yeah. Say like it's definitely your responsibility to do the homework and try to do it on your own and then if you have questions, go to office hours because they can give you a better explanation in that setting compared to lectures.

However, she suggested that the format of the discussion could be changed:

> So basically, the format goes over like a previous quiz, and then he'll just ask if anyone else has questions the homework. And yeah, for me, I mean usually, I try to have those questions answered beforehand. And it's also kind of awkward for me to ask questions…and [the teaching assistant] knows me so I don't really want to ask. But other than that, I think that the discussion is not as helpful…because he doesn't have time to actually go over material review or anything. It's more like all up to the students to ask questions and to do just like, "Hey, can you do this homework problem?" So I don't think it—it’s more just kind of like a Q&A session before the quiz and we don't have time for anything else.

In contrast, Stan noted not only that he did not have time to go to office hours but also that his discussion class constrained his ability to solve the homework: “My [teaching assistant], he's very passionate about math. He's very math- and physics-minded person and communication-wise, he's not the best 'cause he also leans heavily into theory." To Stan, the main purpose of the quiz at the end of discussion was for attendance rather than to test understanding. *Emerging themes*: (a) The discussion class offers homework support, and (b) the discussion class is only a place to take the quiz.

Concerning the ultimate assessment—the exam—Stan believed the exam was good to assess how well he understood the physics concepts being tested: "Exams are good. Once I finished studying for them, I usually feel semi-confident. But obviously, there's room for error in every exam, but if you know it you'll get the answers right, but if you're kinda shaky on it, you'll get them like hit or miss, but if you just don't know it, you won't know it. So that's like basically every other exam." Despite being high achieving, Lucy indicated she was nervous about exams, constraining her overall learning experience: "I want to say I should feel a lot more confident after having taken [an exam], but I still feel like it's kind of the same. Even though I've already taken without [calculus], I still feel like I'm nervous when it comes to the exams and I'm like I don't know because—there's just so many different questions." *Emerging themes*: (a) The exam captures how much the students know, (b) the exam is a mystery to be solved, and (c) the exam creates anxiety.

Regarding the nontraditional learning methods, both accessed the Canvas™ component in order to access practice exams. Although the instructor had recognized online homework as a point of frustration for AL, Stan identified the online homework as a major responsibility: "[I'm responsible] to do the homework and to identify just aspects of the class in which I'm struggling with so I can figure out how to make it so I don't—not to teach myself those things but to make sure that I don't—struggle with them anymore."

Although the homework helped her prepare for the exam, Lucy identified a misalignment with the lectures and the online homework:

> The homework, that usually takes me awhile. It goes from pretty basic problems and they jump into really hard stuff. And also, the homework's due on Monday at 8 a.m. And usually they don't finish teaching the topic until Friday. So usually I try to do the homework ahead of time so I have time to ask questions on it. And obviously I won't know how to do it if they haven't taught it yet. So that's the main reason why I go to office hours, too.

Rather than considering the online homework as the learning obstacle, the students blamed the publisher's site. Stan summarized the experience: "There have been a few times where I've sat down to do the homework and I can't access it, and I've had to clear my cookies for the website several times, once a week in order to access the site itself." *Emerging themes*: (a) Online homework gauges students' understanding, and (b) online homework pushes students to find help to understand information.

Regarding the videos created by the instructor to prepare students for FTF lecture, Lucy never watched the videos, while Stan watched some of them, explaining what aspects enabled AL: "Some of them are pretty lengthy, which is why I haven't been able to watch the other half. I only watch the ones where I need help on that one particular [problem]." *Emerging theme*: Online videos created by the instructor are treated as optional resources.

Both students identified the in-class clicker experience as beneficial. Lucy said the in-class clicker questions were "good for getting the basics down." Stan described his experience:

> Clickers, they're good. A lot of the times you would do the work and you get it wrong, and someone else will tell you the answer and be right. It's easy, not to cheat but to get the right answer. And the work, the clicker questions are very fair, I feel like. Yeah, they're pretty fair. It's not extraneous like you have to sit there do work for five, six minutes, it's a

> one or two minute worth of problem. I work with the people around me and also a little alone if I don't agree with them.

Emerging themes: (a) In-class clicker questions test basic knowledge, and (b) in-class clicker questions instigate small group discussion.

Beyond the instructor’s identified BL affordances, Stan identified other affordances that enabled AL for his physics education. First, he identified his friends as mentors, “And also I have a lot of friends who've already done Physics and did really well. And they would sit down and they would help me figure out a problem, walk me through it, stuff like that. Once or twice, I'll work with a friend doing homework or just to study for the class.” Online he would review YouTube© videos or Chegg® step-by-step problem solutions for textbooks in order to solve homework problems and to understand concepts: “It's my resources, when I have a problem with my problem, sometimes I'll use Chegg®, just 'cause it works it through. And I learn by seeing it done.” Finally, Stan had used notes from Study Edge© and planned to use the tutoring services, especially to help prepare for the exam: “I'm probably gonna use Study Edge© for this exam. I didn't use it for last exam. I think I actually stole my friend's Study Edge© notes for an hour or so…. It's this Friday is when the Study Edge© review is. So I'll only be [at the face-to-face session] for two hours.” *Emerging themes*: (a) Friendly mentors can benefit students, (b) online resources show how to solve problems when students are ready to solve problems, and (c) Study Edge© is a necessary resource to use before taking the exam.

Table 4-2. Constraints and enablements of BL affordances for AL based on PHY 2048 high-performing students' perceptions

BL affordance	Lucy	Stan
	Traditional learning method	
FTF lecture	Enablement	Constraint
In-class demonstrations	Constraint	Enablement
Office hours	Enablement	N/A
FTF discussion class	Constraint	Constraint
Quiz in discussion	Constraint	Enablement
FTF exam	Constraint	Enablement
	Nontraditional learning method	
Emails	N/A	N/A
In-class clicker questions	Enablement	Enablement
LMS	Enablement	Enablement
Course website	N/A	N/A
Online course videos	N/A	Enablement
E-textbook/publisher's site	N/A	Constraint
Online homework	Enablement	Enablement
	Additional learning method	
Friends	N/A	Enablement
YouTube©	N/A	Enablement
Chegg®	N/A	Enablement
Study Edge©	N/A	Enablement

Perspective of average-performing students on the influence of blended learning affordances for active learning

The interviewed average-performing students in PHY 2048 were Chloe and Leo. At the time of the interview their course grade was within the range of a C+ to a B. Chloe, a freshman chemical engineering major, shared that she loved to study chemistry in high school, but once she took university-level chemistry, she realized she appreciated the mathematics side of the sciences more and was considering to change to a math-based major. Visualizing abstract concepts was a challenge for her, so she indicated that memorizing steps and theories in math was easier for her:

> I'm very bad with visualizing things. I'm a straightforward learner. You give me a problem, steps to do it, I'll do it perfectly and everything. But visualizing it, like the x- and y-axis, like, "This rotates around this," and all that stuff. I think if I see it in person it's easier, but just looking at a picture and trying to visualize from that picture and the words what actually happens is a little tricky for me.

A freshman journalism major, Leo took PHY 2048 because he was planning to change his major to computer science offered by the university's College of Engineering rather than the computer science degree offered by the College of Liberal Arts and Sciences. He had taken physics in high school, and remarked, "I definitely enjoy the [science] topics, and it's more interesting to me versus business or finance."

Concerning the traditional learning methods, Chloe and Leo, recognized the same BL affordances as the instructor (i.e., FTF lectures, FTF discussion class, office hours, and FTF exam) except Chloe did not address the discussion quiz or in-class demonstrations as an influence to her learning experience. The FTF lectures enabled both students for AL. Leo remarked, "Yeah, I take some notes. I also follow along, because the professor posts all of his in-class stuff online. But more than anything, I'm just focusing on what he's saying, because I've studied [the information before], it kind of wraps it all up together. So during class I'm just paying attention to what he's doing." *Emerging theme*: Same as the theme from the higher-performing students' section—the lectures are an informative spectacle.

Both students found the traditional learning methods to be challenging. Because she found visualizing concepts challenging, Chloe indicated the discussions did not provide adequate concrete examples, thereby constraining AL to recreate problem solving:

> One of the big problems with physics, I think, is going through the problem fully. I know the previous [teaching assistant] we had before only set them up and was like, "Oh, this is the time. This is the x-coordinate. This is the y-coordinate, and then plug all three of those into this other equation." Well, it kinda gets lost when you don't have the numbers. So I thought that was—I think that was the most challenging part about it.

Leo considered taking the quiz to be the primary reason for attending the discussion class: “It's kind of confusing because my [teaching assistant] kind of goes off in different direction than the professors have and different terminology. Honestly, I feel like no one really pays attention anyways. I'm looking around, but—people just go to take their quiz and then leave. I don't get much of it.” Ultimately, the student considered the exam-taking experience to be uncomfortable: “I just was always an A-student in high school, so obviously coming to college and getting Bs or like, ‘Oh my God, they're so scary!’" Knowing about the weight of the exams was also stressful to Leo: “When it comes to testing, especially here, it's so stressful that it makes you stay awake at night." Chloe and he acknowledged that office hours would probably enable them to understand the information better, but both had never been to office hours. Chloe said the reason was that the “building’s really far away.” *Emerging themes*: (a) Discussions lack visualizing the problems, and (b) office hours inconvenience students. Also mentioned with higher-performing students are: (c) discussion class is only a place to take the quiz, (d) the exam is a mystery to be solved, and (e) the exam creates anxiety.

Concerning the nontraditional learning methods, the students did not mention any experience with emails, and both knew about the online videos but did not watch them. Chloe explained, “I haven't [watched the videos]. But I've heard from people that they're good. I just didn't have time 'cause I didn't really know about them beforehand. I know he mentioned them, but I think I just forgot about them honestly.” She also did not address any experience with the course website. Both students appreciated the in-class clicker questions. Chloe indicated the in-class clicker questions were her “favorite part of the course.” The experience encouraged her to talk to her peers about problems:

> Just 'cause for me, talking to other people about how to do something helps me understand it just 'cause I feel like sometimes teachers are at such a higher level. I feel like they might not tell the students exactly for them to understand, but if you hear it from someone your own age who knows how to do it in a simpler way, it kinda makes more sense to me.

Leo did not stress over the activity because the questions were basic and it was encouraging to know that it was possible to solve the questions correctly: “Under this professor they're good. Because it's more ideas than numbers so he's—he basically wants to test that we understood how to manipulate two equations, but it's not stressful. Basically, it's 95% people get it right as opposed to last semester it would be like 60—55% of people. So I think it's a lot better.” *Emerging themes*: (a) Access to online videos not memorable, (b) in-class clicker questions motivate students to attend lectures, (c) in-class clicker questions encourage students to teach each other, and (d) in-class clicker questions does not instigate stress.

The students accessed old practice exams via the LMS, and Leo was also able to find more practice exams on previous version of the course website. Both students acknowledged the publisher’s site being a constraint to their learning. Chloe complained, “Wiley is not good. It crashes all the time. And I used to be able to do it on Safari©, now I have to use Google© Chrome for it to even load. The page won't even come up on Safari©.” Leo had a similar experience:

> I personally am not too big of a fan. It has a lot of crashes, and it's not great. It's not a great design. They don't run it too well. Like not [the university] but Wiley themselves. It's kind of a hassle because like every other day you want to go on it, if you want to use it, you have to go and clear your browser history and then log back into Canvas™. And if you're focused and determined to do the work, it just kind of throws you off.

The students differed in their opinions of the online homework as an affordance. Chloe recognized completing the homework was one of her main responsibilities in the course, and they enabled her to practice and to do well: “Definitely keep up with the homework, just 'cause honestly I think the homework are easy points. I think if you could get easy points in a class, you should definitely take advantage of them.” However, for Leo, the online homework constrained him from learning proper steps for problem solving:

> So like basically, you get five tries. It's 10 questions, and then each question can have whatever random number of subquestions. And no matter what, you get five tries, so what could be a question that is one question and you get five tries, it was one that it was one question, but in that question is six questions, and you still only get five tries. And like a lot of the times, you need the question before it, and you can never check if you're right. So you can do all the work with the number you got wrong.

Being unable to problem solve on his own, Leo used an additional resource, Chegg®: “If I'm confused, I'll just—I like—basically I would just get through like using Chegg® or something. And then I'll go back and then actually solve in. And I completely understand what I'm doing but maybe like two to three hours.” *Emerging themes*: (a) Unreliable publisher’s website prevented access to problem solving, (b) online homework provided easy practice, (c) online homework frustrates AL due to its reliance on the succession of correct answers, and (d) additional online resources dispel confusion for problem solving.

Finally, similar to Leo, Chloe also addressed additional BL affordances to AL. Chloe reviewed the physics content with her friends, and she reviewed Study Edge©

materials, particularly the videos: “They have chapter videos usually once a week. I would say those are about an hour and a half to two hours because I like pausing it and writing it down and trying to grasp the information. And then obviously when there's an exam the week before, I do a lot more work.” With Study Edge©, she had the top $75 package (the tutoring service had different payment tiers from $25 to $75, which allowed for different affordances such as less or more hours to watch videos or access to FTF reviews about the textbook chapters). Leo also worked with friends but for moral support rather than for problem solving. He attended the Study Edge© live review sessions, and spent time to review its practice exam questions. However, he realized the experience with Study Edge© had given him false confidence, in that he would read the solutions rather than attempt to solve the problems on his own: “I know that I can find the right way to do it if I go [to Study Edge]. So knowing that I guess makes me like not try or not like go as hard to try and find the solution myself.” *Emerging themes*: (a) Study Edge© is a student-trusted course that students believe will help them do better on the PHY 2048 exams, and (b) Study Edge© can give students false confidence.

Table 4-3. Constraints and enablements of BL affordances for AL based on PHY 2048 high-performing students’ and average-performing students’ perceptions

BL affordance	Lucy	Stan	Chloe	Leo
		Traditional learning method		
FTF lecture	Enablement	Constraint	Enablement	Enablement
In-class demonstrations	Constraint	Enablement	N/A	Enablement
Office hours	Enablement	N/A	N/A	N/A
FTF discussion class	Constraint	Constraint	Constraint	Constraint
Quiz in discussion	Constraint	Enablement	N/A	Constraint
FTF exam	Constraint	Enablement	Constraint	Constraint

Table 4-3. Continued

BL affordance	Lucy	Stan	Chloe	Leo
		Nontraditional learning method		
Emails	N/A	N/A	N/A	N/A
In-class clicker questions	Enablement	Enablement	Enablement	Enablement
LMS	Enablement	Enablement	Enablement	Enablement
Course website	N/A	N/A	N/A	Enablement
Online course videos	N/A	Enablement	N/A	N/A
E-textbook / publisher's site	N/A	Constraint	Constraint	Constraint
Online homework	Enablement	Enablement	Enablement	Constraint
		Additional learning method		
Friends	N/A	Enablement	Enablement	Enablement
YouTube©	N/A	Enablement	N/A	N/A
Chegg®	N/A	Enablement	N/A	Enablement
Study Edge©	N/A	Enablement	Enablement	Constraint

Perspective of low-performing students on the influence of blended learning affordances for active learning

The low-performing (C or below) students interviewed were Isaac and Rachelle. Isaac was a freshman majoring in computer engineering who had never taken physics before and was “not the biggest fan” of the subject, but need to take the course for his major. Rachelle, a sophomore in industrial engineering, also took the course as a requirement. The course was also her first exposure to physics. Compared to the other students interviewed, the low-performing students spent the most time studying for the course. Isaac spent about 10 to 12 hours a week working on physics-related work outside of the FTF class time, while Rachelle studied up to six hours a day for the course.

In regard to the traditional learning methods, aside from office hours for Isaac, the students mentioned all the instructor-identified BL affordances. Isaac considered it his responsibility to attend the FTF lecture but found the affordance to be a constraint on AL: “Well, [the lecture size is] really big, so it's easy to zone out a lot of times. I often find myself on my laptop just doing other stuff, not paying attention, because it's not hard to hear, but it's easy to get distracted when there's so many people in the classroom.” Rachelle also felt similarly about the format of the FTF lecture as a constraint to AL by not helping her comprehension, and preferred office hours as the place to problem solve: “I feel like I get more just going to office hours than the actual class, 'cause, yes, I eventually learn from his lectures, but I have to go back [and review notes] and it's also very tough because everything's on a PowerPoint. And it makes it hard to see, sometimes, in the PowerPoint.” The demonstrations during lecture helped Isaac to begin to engage in AL; he noted, “I actually pay attention when he does it 'cause it's different from him just lecturing. So, when there's something loud in the room, popping, it's hard to not pay attention to it.” Nevertheless, Isaac considered the discussion class to be the place to problem solve: “The discussions, I feel like they're more helpful than the lectures, 'cause they're doing the homework problems for us. I just need to see how they went and did the process of them solving the problem. And that's why seeing it firsthand helps me understand it more clear.” He did not attend office hours, as he explained, “Most of the times they either conflict with my other class times, or I just have too much other work to do.” *Emerging themes*: (a) Lectures can be a place for students to hide, (b) information in lectures is not accessible to all students, (c) office hours facilitate better discussion for problem-solving steps, and (d) demonstrations in lectures become the spectacle. Similar to the themes for the high-performing group, (e) discussion class offers homework support.

Despite not having time to attend office hours, Isaac devoted time to the additional BL affordance Study Edge©, which enabled AL experiences for him and improved his performance on quizzes and the exam. About his experiences with the quizzes he shared, “I feel much better because, in the beginning, for all of my quizzes in discussion, I wasn't doing as well. I was getting sixes out of 10. But then, after doing Study Edge©, I'm getting eight out of 10…. And with how I'm doing my quizzes, I just need to average nine out of 20 in the last two exams to get a C.” *Emerging themes*: (a) Instructor-provided BL affordances are not worth students’ time compared to Study Edge© BL affordances, and (b) quiz grades improved by Study Edge©.

Rachelle’s ability to solve questions in the quizzes and in the exams hinged on her ability to solve questions in the online homework:

> I realize that the quizzes are exactly like the homework. The exams are easier than the homework. If I really understand the homework, then I'd understand the exams. I think it's really just making sure that I understand the homework and doing the problems….The last exam I took, I was upset because it was actually one of the easiest exams I've seen. Honestly, at least six of those questions were nearly exactly like a homework problem. But I was upset at myself because I didn't take the extra time to understand the homework.

To assist with the online homework, Rachelle was the only interviewed student who explored the publisher’s website beyond the assigned online homework and found a function in the site where similar questions to the homework were available for additional practice for students:

> I honestly think it's helpful, actually….'cause I saw this tab that said Orion Build Your Proficiency, and it takes questions from the homework and it makes sure that you understand it. I think that's pretty helpful…. With the

> Orion, when I first started physics, I was really scared, so I looked at every tab possible to see what could help me. And I found Orion.

Emerging theme: Student performance in online homework indicates exam performance.

Similar to Rachelle, Isaac expressed it was his responsibility to understand and to complete the online homework, yet he also indicated that the online homework was a constraint to his learning because nothing else in the course had prepared him to solve the problems in the homework:

> Honestly, I think [the homework is] really difficult, because I feel to just explain the concepts in class doesn't really prepare you for the WileyPLUS©…. So then when I actually sit down in front of the computer and I attempt to do it, I don't know where to start. I know the material, the equations to use, but I just know... I think the hardest part about physics is knowing how to draw the picture, because the picture is very important in the class. Every problem you do, you have to draw a picture to help you understand the question, to solve it.

To assist him with the homework, Isaac used Chegg©: "Another source I use is Chegg©, especially for the online homework, because when I don't understand a question and I don't know where to go or, also when I'm running out of time, I usually just—they have a bunch of people post the question, they show the whole solution."

Emerging themes: (a) Lectures do not prepare students to visualize concepts. Similar to the theme mentioned with the high-performing group, (b) online resources show how to solve problems when students are ready to solve problems.

Although Isaac watched the instructor-prepared online videos as a way to reflect on crucial concepts, he chose to watch more Study Edge© videos instead to enable him to solve problems: "Usually the online videos [from the instructor] help, but they're very time-consuming, so I place more priority on the Study Edge© videos, because those are the ones that actually help me in my discussion quizzes. Because they're going over the actual questions, while the online lectures are just going over concepts." *Emerging theme*: Study Edge© targets information to be tested on the exam.

Both students recognized the in-class clicker questions encouraged them to problem solve for extra credit. Isaac shared that when answering the questions he was able to discuss with other students potential answers:

> The clickers, I think for lectures, they're the most helpful, but also they're also the reason why I go to class because they give 5% extra credit on your final grade…. I feel like that's the most helpful out of a lecture, because when the professor tends to speak about concepts also, I zone out, but when he does the clickers, it actually relates all the material that he's talking about into a question, 'cause those are one of the few questions they do in class. It's usually, they ask three questions in a row, but they're all very similar. And then, also, after class, answers the clickers and the results are shown, he usually goes over the question. He solves it out fully. So, that's why I find that helpful.

But Rachelle said the experience did not help with thoroughly understanding physics concepts and problems: "Truthfully, I don't like clickers at all. I'm doing well on the clickers actually, but I just don't like it. I don't think it's a way to actually help students learn. Now, the clickers are a lot more helpful since it's like how you should work out the problems in the homework, but I still don't think it's a way to help students learn." *Emerging themes*: Similar to the theme found with the average-performing group, (a) in-clicker questions do not instigate stress since they are extra credit, and (b) the in-clicker questions encourage student explanation.

Both did not mention the course website as an affordance but went to the course LMS for practice exams. The emails sent from via the LMS informed Rachelle of an opportunity to participate in a study group: "It was somebody just posted on the discussion and said, 'I'm starting a study group. Who wants to join?' And I just joined." Different from the other students interviewed, Rachelle joined a study group without knowing anyone in the group, while the others either worked with friends who already took the course or people they knew from class. Although she did reach out to friends and the university's Office of Academic Support (OAS) for tutoring help, both did not enable her to solve problems on her own: "I used to get help from [friends] who took the class already, but I stopped doing that because I realized that if they took the class already, then they're probably busier than I am….I used to always go to [OAS], but I found out that it was not working for me either, because I would finish my homework early but then after I leave them, I wouldn't understand it later on." Through a student support service, Rachelle was given a voucher to use Study Edge© for her studies, and she indicated that watching the exam reviews and chapter reviews helped her to better solve problems. She did not indicate that she watched the instructor-created videos. Although Rachelle attempted to solve the homework problems on her own, she used Google© to help find solutions if her notes did not help:

> I was looking at the homework problems, looking back at the notes, looking at… the extra notes that Doctor [Sanchez] would record in the actual class and it was just not helping. Those notes would kind of help, but not really, because most of the questions on the homework require equations to do it. I couldn't get the equations and it didn't work out at all. I was focusing on one homework problem because I didn't want to be like those students that searched it up on Google©, but that's what it ended up resulting anyways.

Emerging themes: (a) Discussion in LMS facilitates small groups, and (b) tutoring support gives students false confidence. Similar to themes in the high-performing group and the average-performing group, (d) Study Edge© is a necessary resource to use before taking the exam.

Table 4-4. Constraints and enablements of BL affordances for AL based on PHY 2048 high-performing students', average-performing students', and low-performing students' perceptions

BL affordance	Lucy	Stan	Chloe	Leo	Isaac	Rachelle
			Traditional learning method			
FTF lecture	Enablement	Constraint	Enablement	Enablement	Constraint	Constraint
In-class demonstrations	Constraint	Enablement	N/A	Enablement	Enablement	N/A
Office hours	Enablement	N/A	N/A	N/A	N/A	Enablement
FTF discussion class	Constraint	Constraint	Constraint	Constraint	Enablement	N/A
Quiz in discussion	Constraint	Enablement	N/A	Constraint	Enablement	Enablement
FTF exam	Constraint	Enablement	Constraint	Constraint	Enablement	Constraint
			Nontraditional learning method			
Emails	N/A	N/A	N/A	N/A	N/A	Enablement
In-class clicker questions	Enablement	Enablement	Enablement	Enablement	Enablement	Constraint
LMS	Enablement	Enablement	Enablement	Enablement	N/A	Enablement
Course website	N/A	N/A	N/A	Enablement	N/A	Constraint
Online course videos	N/A	Enablement	N/A	N/A	Enablement	N/A
E-textbook / publisher's site	N/A	Constraint	Constraint	Constraint	N/A	Enablement
Online homework	Enablement	Enablement	Enablement	Constraint	Constraint	Constraint
			Additional learning method			
Friends	N/A	Enablement	Enablement	Enablement	N/A	N/A
Study group	N/A	N/A	N/A	N/A	N/A	Enablement
YouTube©	N/A	Enablement	N/A	N/A	N/A	N/A
Chegg®	N/A	Enablement	N/A	Enablement	Enablement	N/A
Study Edge©	N/A	Enablement	Enablement	Constraint	Enablement	Enablement
OAS	N/A	N/A	N/A	N/A	N/A	Constraint
Google©	N/A	N/A	N/A	N/A	N/A	Enablement

Researcher's review of documentations of blended learning affordances for active learning in PHY 2048

Course documentations were electronic and found on the Canvas™ LMS (see Figure 4-1) but isolated mainly to the course website (see Figure 4-1). Following Elo and Kyngäs's (2008) recommendations for content analysis, the documentations were reviewed, and the location of and the codes related to the documentations noted in an online spreadsheet. The unit analysis determined was BL affordances presented to the students, and the grouping of the codes were based on the study's conceptual framework of how the BL affordances enable or constrain AL (first theoretical proposition).

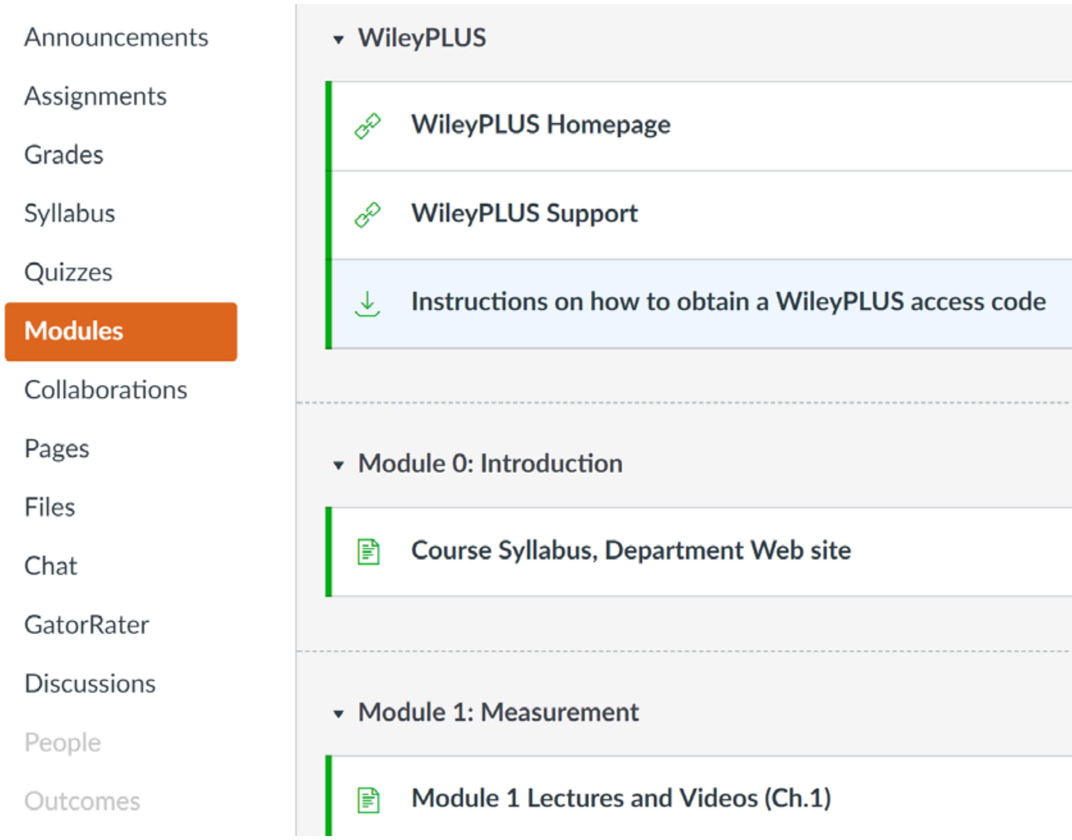

Figure 4-1. Snapshot of PHY 2048 Modules section in LMS with links to online homework, course website, and instructor-recorded videos.

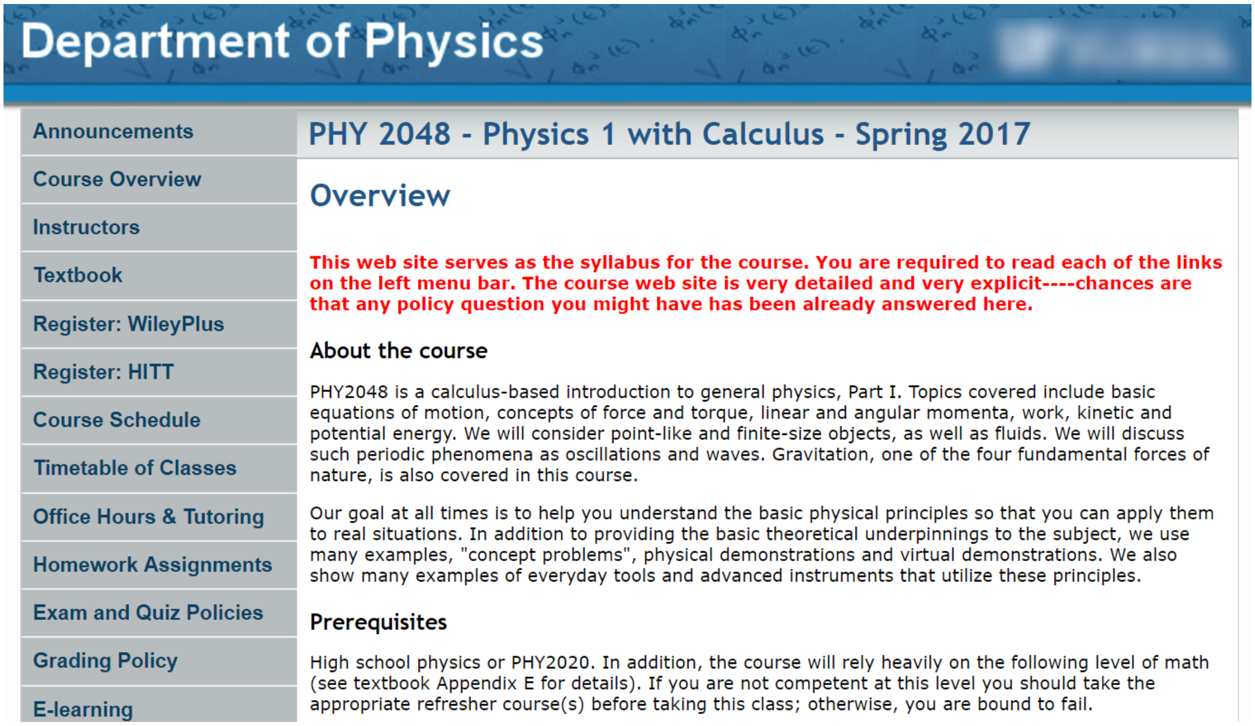

Figure 4-2. Snapshot of the PHY 2048 course website.

On the front page of the course within the LMS, the welcome message noted that the course website would act as the course syllabus. On the course website that acted as the umbrella documentation for the course were course announcements, a course overview, required materials, and assignment expectations. Within the announcements was the explanation that that the publisher's website was down, and the students could receive e-materials at a discounted price. Thus, although the publisher's website constrained AL, the instructor and the publisher offered to provide other BL affordances for AL to replace that constraint. The announcements also included information about the upcoming exam, as well as an extra credit opportunity to complete the researcher's survey. The following is an example of an announcement (original included hyperlinks):

> The second exam is in 9 days, Mar.24, Friday night, 8:20-10:10PM. It will cover chapters 7-12. The room to take your exam depends on the first letter (or letters) of your LAST name…You must attend the correct room or you could receive a zero for the exam. Also, please record your exam

> code when you receive your exam for future reference. Due to FERPA regulations we cannot hand back your exams in class. Note that exams are closed book. Basic formula sheets will be provided - you do not need to bring any. It is available here. Material you are allowed to bring, including a calculator, is listed here. An example of how to properly find and record the exam code on your Scantron® answer sheet is here.

In case students worried about their grade before the exam the extra credit opportunity—the exam being a possible constraining BL affordance was mitigated by an opportunity to complete an online survey. Also in the announcements on the course website, the instructor referenced the university's tutoring center to encourage students to find help before the exam; this was one affordance that was not mentioned in any of the other data collected.

Concerning the information in the course website's Overview section, the instructor outlined that by the purpose of the course was to help students to:

- Analyze particular physical situations, and thus identify the fundamental principles pertinent to those situations;
- Apply fundamentals principles to formulate mathematical equations describing the relation between physical quantities in these particular situations;
- Solve mathematical equations to find the values of physical quantities;
- Communicate unambiguously both the principles that apply to a situation and the results of specific calculations resulting from the steps above.

The instructor also noted that, as "required work and points toward your final grade," students should read the text or assigned material, attend lecture and complete the in-class clicker questions, watch online lectures in the LMS, complete online homework (noted as the most important element in the course), and attend the discussion class—identified BL affordances for AL. In the explanation for the BL affordances, the instructor shared his expectations:

> Invest the time! From interviewing students we have found that the A to B+ students have better habits and spend more time on this course than B and C students. In particular, they rarely miss class, do all the recommended homework problems and more, read ahead, watch online lectures, and study the material for several hours a week (not just before exams). Developing good habits at the start of the semester, before things get busy and you fall behind, will help you succeed. A large fraction of your study time should be devoted to problem solving, which is *essential* to learning and cannot be replaced by mere listening and reading.

The instructor further explained that during lectures students should not be “reading papers, browsing internet, texting/emailing, doing homework;” rather, students should ask questions, emphasizing “your question is not stupid and is probably widely shared.” The homework was to enable students to practice problem solving on their own. Before working on the problems, students were expected to review chapter summaries and to understand the exact meaning of each formula. Students were encouraged to “not give up easily,” and the instructor highlighted: “If you get stuck (which is *absolutely normal as your learn!*), do not hesitate to consult with your friends and certainly take advantage of office hours.” If students did have additional questions, the instructor encouraged the students to attend office hours or to email the instructors. Within the LMS the instructor provided practice tests with solutions, and he encouraged students to use the chat feature within the LMS to ask each other questions—another BL affordance that was not expressed in any of the interviews. Based on the results of the content analysis, Figure 4-5 is a conceptual map of the identified BL affordances that enable (in green) or constrain (in red) AL and how they influence AL (items from Meyers and Jones’s (1993) AL framework noted on each of the lines). The acronym NSH represents that the instructor provided “no specific how” the BL affordance enables AL.

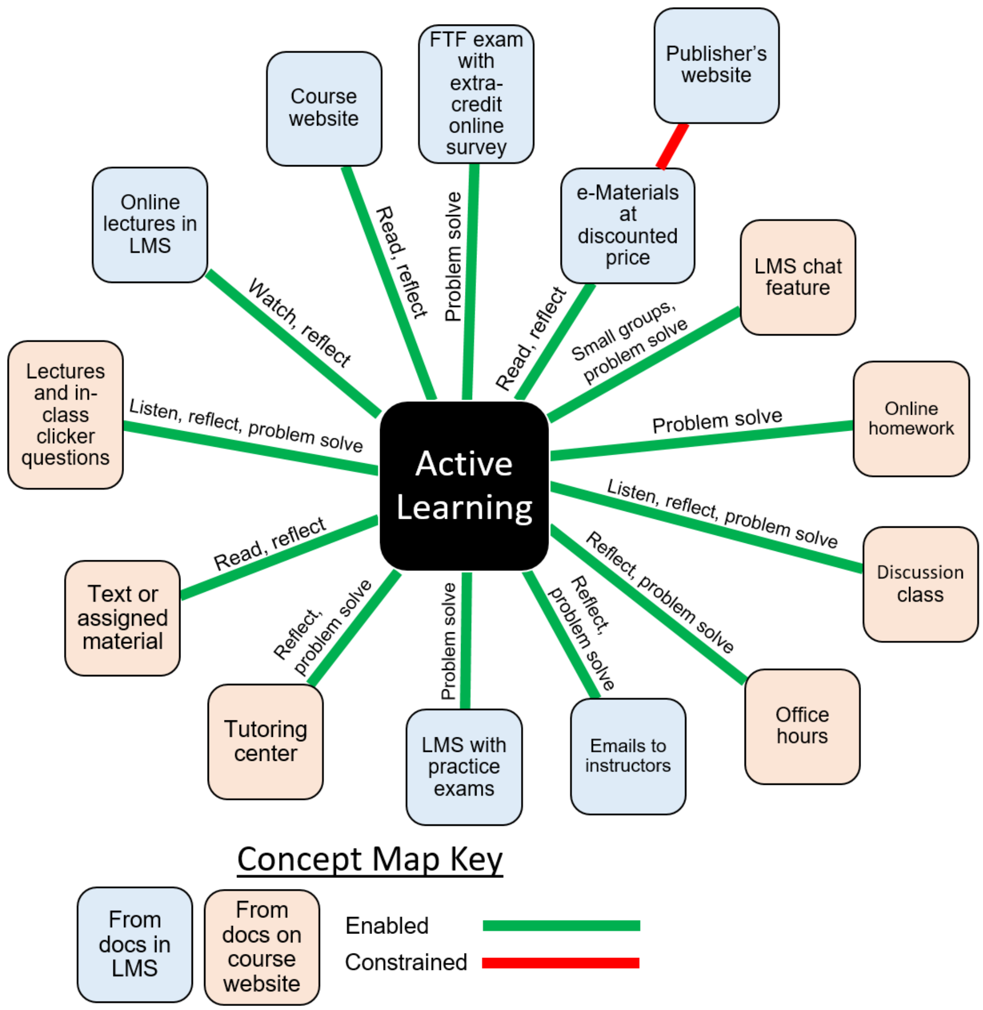

Figure 4-3. Conceptual map of the influence of BL affordances on AL according to the PHY 2048 documentations.

Researcher's observations of blended learning affordances for active learning

Face-to-face learning environments. The researcher used PORTAAL to assess the AL during two lectures and one discussion class, which were constituted of BL activities (e.g., traditional learning method of FTF lectures and nontraditional learning method of in-class clicker questions). Figure 4-3 through Figure 4-5 are university photos showing the setup of the lecture halls and a classroom for discussions.

Figure 4-4. Photo of larger PHY 2048 lecture hall (photo obtained with permission from a large public university in the South).

Figure 4-5. Photo of smaller PHY 2048 lecture hall (photo obtained with permission from a large public university in the South).

Figure 4-6. Photo of a classroom similar to the one in which the observed PHY 2048 discussion class was held (photo obtained with permission from a large public university in the South).

The setup for the lectures and discussions both encouraged more instructor-student interactions rather than student-student interactions due to the seating facing the front of the classroom where the instructors stood. If there were any student interactions, students would need to communicate with other students immediately around them.

The lectures and the discussion classes often were the only times in which the students have any type of interaction with the instructor or teaching assistant, respectively, so the observation scores from both environments were averaged in the assessment of AL. The scores, as detailed in Chapter 3, related to one of four dimensions: practice, logic development, accountability, and apprehension reduction.

For the first dimension of practice, students had the possibility of talking through content 76% of the class time. Lectures were 50 minutes long, and the discussion class was divided into 35 minutes for reviewing homework and 15 minutes for students to complete the quiz. Aside from the instructor's lecture time, students had the class time to ask questions or talk to each other about the content. The teaching assistant showed how to solve homework problems, so throughout the process she asked the students for their input. The students were not allowed to talk to each other during the quiz time. Whether in lecture or in the discussion time, the instructor or the teaching assistant reminded the students to use prior knowledge for 77% of the activities. The format of both lecture and discussion encouraged students to build upon the information being presented to them. For example, in lecture the instructor discussed definitions of terms at the beginning of class, asked if students understood the definitions, lectured about new information, and quizzed students about the new information through the clicker questions. However, among the activities only 33% of activities did the instructor or teaching assistant hear individual student answers and have the opportunity to respond. The instructor and the teaching assistant would pause about five seconds and ask if students had questions, or they would pose questions to students and wait about five seconds. Especially in the lectures, students did not answer or ask questions, so the instructor would either continue lecture by answering his own question or move on to the next activity. During class time 33% of the activities required higher order skills; this was often seen in the problem-activities like the clicker questions or the quiz. Nevertheless, 100% of the exam demanded higher order skills because students were required to exercise critical thinking in applying multiple physics and calculus concepts to solve problems.

For the second dimension of logic development, 33% of activities included problems that required students to use higher order skills (e.g., application, analysis, evaluation, and synthesis)—similar to the reason as presented in the dimension of practice. Although 93% of activities reminded students to use logic before student engagement, 17% of activities explicitly gave students time to think alone before having to talk in groups or in front of the class or before answering clicker questions on their own. Also only 17% of activities required students to work in small groups during student engagement—the only opportunity enabling work in small groups during lecture or discussion was the clicker questions. Between iterations of student engagement 85% of activities provided no hints, which encouraged students to consider solutions on their own. Among the activities 33% of them required students to share their logic in front of the whole class, and 33% of them where the correct answers were explained. There were no activities in which alternative answers were explained during a debriefing session—no logic explained for why incorrect answers were incorrect.

For the third dimension of accountability, 33% of the activities (the clicker questions and the quiz) were worth points, and 17% of activities required small group work demanding that students participate—again, the clicker questions in lectures. In order to avoid volunteer bias, Eddy and associates (2015) recommended that instructors randomly call students; 0% of the activities included random calls.

For the fourth dimension of apprehension reduction, the use of cold calls would have provided students with practice to participate, but no activities used random calls. When students did participate, 30% of the activities did the instructor or the teaching assistant provide praise to the whole class and 23% of activities to praise an individual student. At no time did the instructors give negative feedback. During student engagement activities, in 25% of the activities the instructors reminded the students that errors would be part of the learning process, and during 62% of activities the instructor emphasized hard work over ability. During the observation of the discussion class, the teaching assistant told the students that one of the quiz questions was very challenging, and that the students should just do their best because that question had been made extra credit.

Online learning environments. In order to “observe” the online learning environment, the PORTAAL was used, but rather than a percentage being generated, evidence, or the lack thereof, of the four dimensions was noted. Within the course’s LMS as the online learning environment for the students, the instructor made transferred practice exams into the form of ungraded quizzes. Having the practice exams available to students for their use at any time supported three items within the PORTAAL first dimension of practice: (P1) allocating class time for practice, (P2) using questions aligning with exams, and (P3) including questions requiring the use of prior knowledge. Within the LMS there was no evidence of (P4) the requirement of students to explain their answers in front of the whole class for feedback from the instructor. Nevertheless, although there was no requirement, the instructor and students did participate in online discussions. When WileyPLUS© was unavailable to students, the students went to the discussion forum to communicate that the site was down and to share whether the site was available again. Additionally, students were able to commiserate the situation—one student responding in frustration with the comment, “Welcome to WileyMINUS!” The instructor replied to students after 43 comments that he recognized the site was down and that the homework deadline would be extended; ultimately, 51 comments total were made on the thread. In one discussion about the publisher’s site not working again, the instructor did not reply but students expressed solutions to the student who initiated the discussion. One student also used a discussion to bring together other students for a study group. He posted information to a group messaging service called GroupMe© so that students could connect with each other to arrange the study group. Whether they met to study, 29 students joined the group message. The affordance was indirectly touched upon by Rachelle when she said she received emails via the LMS about study groups.

Regarding the PORTAAL second dimension of logic development, the practice exams allowed students (L1) to practice critical thinking to solve problems and (L3) to have adequate time to solve problems alone before any other form engagement. The replies in the discussions and the online resources linked in the course provided hints to some students, thereby not meeting (L5) the recommendation that students not be revealed hints. There was no evidence of (L2) reminding students to explain their answers, (L4) requiring students to discuss in groups before the whole class (although discussions were allowed), (L6) asking students to explain their logic, (L7) strong explanation of the logic behind correct answers, and (L8) strong explanations as to why the alternative answers were wrong (although the students' presenting their wrong answers and asking why did encourage brief discussions as to why that answer was incorrect).

There was no evidence supporting the third dimension of accountability. The online environment encouraged practice and question-asking, so there were no examples of (A1) activities worth points, (A2) the employment of small groups (although the discussions naturally facilitated a small group of people asking and answering questions), and (A3) random calls for students to answer questions.

Although the environment encouraged a reduction of apprehension, in that people could participate as much as they wanted in the online environment, the instructor did not (R1) randomly call students to participate, (R2) praise class effort, (R3) thank the students for their contributions to a large discussion, or (R5) remind students that mistakes were necessary in the learning process. The instructor did (R4) avoid demeaning the students' questions and answers.

Addressing Proposition 2: Relationship between Blended Learning Affordances and Active Learning Encourages or Discourages Student Persistence

Based on Graham and associates' (2013) student persistence framework, students were asked directly about their motivation, confidence, science learning, and identification as a scientist. Evidence used in response to the first proposition was also appropriate as responses to the second proposition.

Students' perspective related to their motivation, confidence, science learning, and identification as a scientist

Motivation. When asked about their motivation to persist in the course and in the sciences, one of the high-performing students, Lucy, identified her non-course experiences in a behavioral medicine research lab have motivated her to persist in her studies. The "leadership and responsibility" she has encouraged her to be more professional with her work. In response to what motivated him, the other high-performing student, Stan, stated in response, "I would like a good grade." As an engineering major, he was required to complete the two-part series of introductory physics courses. Grades continued to motivate the average-performing students. *Emerging themes*: (a) Good performance in a course supports sense of professionalism for students, and (b) earning good grades keeps students on career path.

Chloe wanted to earn at least a B in the course, but the in-class clicker questions also motivated her to attend class. Rather than focusing on the points associated with the clicker questions, Chloe had said, “And obviously some days I'm like, ‘Oh, I don't wanna go,’ but I still do just 'cause I'm always scared if I miss a class, I'm gonna miss something really important. So I think that really motivates me to go.” For Leo, he was also an engineering major and obligated to pass both the introductory physics courses. *Emerging theme*: (a) In-class clicker questions draw students with important content information, and, similar to the high-performing group, (b) a career goal fueled the motivation to remain in the course.

One of the low-performing students, Isaac, also credited the desire to be an engineering major as the motivation to continuing in the course: “I would say, not more motivated, but I would be very disappointed if I put all this work in, and I didn't, and I would have to drop the class in the end. But either way, I have to stay in the sciences, because I'm an engineering major. So I'd have to eventually take Physics 2.” The student wanted to remain in the course and see his final course grade, having invested 10 to 12 hours a week to studying for physics and subscribing to Study Edge©. The points he earned from the in-class clicker questions also encouraged him to believe he had enough points to pass the course. Despite being a low-performing student, when Rachelle was asked what motivated her to continue studying physics, “understanding it” was her reply. *Emerging themes*: (a) invested time and money root students in a course (e.g., purchase of Study Edge©), (b) in-class clicker questions as easy points make passing course more attainable, and (c) personal understanding drives motivation.

Confidence. Through her research responsibilities, Lucy felt more self-confident to meet course-related expectations than if she did not have the responsibilities: “I mean overall I think it gives me more self-confidence just because of the leadership positions I have and I guess that would affect how I view myself in becoming a physicist.” Although he was one of the high-performing students, Stan did not feel confident in the course:

> Not too confident because I need definitely to study. A lot of the things that he does in class, I can see him as he works it through. I can see where he's getting everything, and I kind of understand it. But if I sit by myself and I'm given that problem, I'm just gonna blank. So I can see where he's coming from, but I'm also not confident in the material. I'm not confident enough in the material to do it on my own.

However, Stan’s desire to earn a good grade motivated him to continue in the course. *Emerging themes*: (a) External research experiences contribute to sense of confidence, and (b) inability to problem solve on one’s own lessens confidence.

Chloe was unable to articulate why she was not confident with physics: “I don't know. It's hard for me. It's weird 'cause I'm good at math, so you would think I would like physics. I feel like it's kind of mix between math and science-ish.” The science aspect of physics challenged her. Leo attributed his confidence to Study Edge©: “It definitely does give me a piece of confidence. I guess you can say, just it sounds things that are a little bit better and since these guys like they know the test so well. They're doing these for five years, six years. They know the patterns. They know what teacher's going to ask.” However, Leo also realized that Study Edge© gave him a false confidence: “Like I didn't do well in the first exam, but I feel like I would've been a lot worse without it. But I also think that it can give me a sense of like false confidence because what you're going to get [on the exam] is different from what [instructors at Study Edge© are] going to give.” *Emerging themes*: (a) Specific topics being covered can lessen or strengthen confidence, and (b) Study Edge© empowers students to solve problems but possibly not problems similar to the ones on the PHY 2048 exam.

The exams influenced Isaac's confidence, lowering his confidence but, at least, providing him parameters on how to pass:

> I wouldn't say, overly confident, but I feel confident enough to get to pass. Because the first exam, I went into it not feeling very confident, knowing I was gonna fail, but I managed to get six out of 20. So I only needed to get nine out of 20 to pass on the last two exams. So I feel like that's very doable with the amount of work I've put in since exam one.

To help him pass with a C, Isaac credited Study Edge© as the reason he improved his quiz grades, which alleviated the stress on the grade needed on the exams to pass the course. For Rachelle, grades also influenced her confidence. An adjusted passing percentage for the course was 55% (letter grade C). Through her learning experiences, Rachelle's confidence increased as her grades improved: "[I'm] a lot more confident, 'cause when I started, I was probably 15% almost. Now, I'm like a good 56." At the beginning of the course she reported studying for up to 30 hours a week; by the time of the interview, she said she studied up to 15 hours a week and credited the decrease in study time to the course's focus being shifted to solving math problems rather than visualizing concepts. *Emerging themes*: (a) Exam grades provide reference point to how much students should be confident, and (b) confidence results from trial and error of BL affordances.

Science learning. Needing to take the physics course again but with calculus due to changing her major from pre-medicine to medical physics, Lucy indicated she learned to problem solve and to apply the information to real-world situations:

> But I don't know. After I stopped taking it [the first time] I was kind of like feeling something was missing in my education. It was weird. I like how it describes how a lot of things in the world work. And it's not like a lot of the

> med classes where you have to memorize a bunch of things. I like how you learn how to interrupt certain problems and can solve a ton of them. It's not like you're memorizing how to do a certain thing….After I stopped taking physics, the next semester I was just taking, anatomy and biochem were my main classes. And that's just straight up memorizing stuff and I hated it. I missed just doing problems for studying and stuff. And the teachers for physics, I seemed to really connect with them, compared to the medical—the more chemistry and those kind of courses.

She also attended office hours to obtain more explanations on solutions to problems, yet, despite being a high-performing student who was chose to minor in physics, she was still unsure about her performance on exams because there were “so many different questions [the instructors] can ask” that require the use of various formulas. Stan also voiced an appreciation for similar problem-solving experience within physics:

> It's mainly a practice type thing. 'Cause the more you see it, the more you can pick things out and start applying them into equations. Also having someone not tell me how do to it but also describe to me what I'm doing and also seeing it in my head….I'm a little bit of a visual learner, but if I can see it happening and see what the forces are….I draw pictures, and then I can manipulate them and figure out what's going on.

Helping him in the process of learning new concepts was Chegg©, which illustrated where values went within the equations. After using Chegg© and practicing to solve problems on his own, Stan felt confident that he could study for and do well on the exams. *Emerging themes*: (a) Learning physics is rewarding due to real-world applications, (b) downfall of real-world application of physics problems is there are numerous, different problems, and (c) applications that illustrate problem-solving like Chegg© encourage science learning.

Chloe shared that her learning experience excelled when the course focused on mathematics problems because, to her, “one of the big problems with physics I think is going through the problem fully.” She was not challenged by following mathematical problems, but by visualizing different problems: “I feel like math, you don't have to think as much about what to do. Just if you know what to do, then you apply it and you follow the steps. And also physics, all the problems are different." However, talking to other students about the in-class clicker questions helped Chloe to understand the steps to problem solving. Leo expressed his enjoyment for learning physics, but testified that the exams spoiled the experience: "Because it's really cool. It's a lot of nice things you would never of known. It explains everyday life and how everything works, but then they put questions to fool you. And then it just kind of—then, in the end, you're just learning to pass a test, not to understand." *Emerging themes*: (a) Either the science or mathematical aspects of physics encourage or discourage science learning, and (b) visualizing concepts can be a challenge to science learning, (c) designated times to talk through problems can assist science learning (e.g., discussions related to in-class clicker questions), and (d) the stress of testing diminishes the enjoyment of learning physics.

Isaac had never taken a physics course before, so when he compared himself to other students, he felt he had more to learn:

> I'm not the biggest fan of physics 'cause I didn't take it in high school, and that's why I'm not doing as well, while all my other friends, they took it in high school so they have background. So that's why they are doing decent right now. All the material's really new to me, so it's taking me a lot to understand the concepts, drawing out every problem.

Assisting him in the learning process, he identified the top three BL affordances have been attending lectures, watching the instructor-recorded online videos, and using Study Edge©. During the lectures Isaac was able to see how the instructors presented and solved problems: "I think the lectures definitely appeal to the visual senses, because the live examples help you understand the concept a bit more." He appreciated the flexibility of watching the online videos at his own pace: "I understand it more, because I can pause and go back if I didn't understand the concepts. And I feel like in lecture, you can't control the pace, because it's based on the professor. And also online, they go into a lot more depth. They go into the background that you need to know." The use of Study Edge© further dissected the concepts being studied, as well as provided more practice problems:

> They explain it more clear, and they give chapter reviews after the professor goes over it in class. And I think those are much more easier to understand, and they break it down for you. They give you practice ones, 'cause I feel like in class they go over more concepts and not the problems, while in Study Edge©, they actually go over each problem, they take you through each problem and how to do it.

Rachelle had also not taken any physics course before PHY 2048. As a summary of her learning experiences, which also boosted her confidence, Rachelle attended lectures, completed the online homework with guidance on the publisher's website, and studied as much as she could with the help of instructors in office hours and other students in her study group, Google©, and Study Edge©. She described learning about physics as "kind of difficult but it seems very useful because everything that we're learning, it seems to apply to life in general." Because grades helped Rachelle to gauge how much she learned, as mentioned in the Confidence section, she improved her course grade from a 15% to a 56%. *Emerging themes*: (a) A combination of BL affordances is required to scaffold new students from reading a problem to solving one, and (b) an appreciation for physics does not mean that one will do well in the course.

Identification as a scientist. Lucy regarded being a scientist as more than taking one physics course: "I feel like I'm not there yet, but I'll be getting there one day. I just feel like I need more experience with physics, and physics is basic stuff. So I feel like I would need that level kind of stuff. And a lot applies to medicine, for example, since that's kind I want to go into, but I just think I need more experience overall." Lucy did indicate that she already worked in a behavioral medicine research lab, and conducted focus groups and transcribed interviews. However, she did not reference those experiences to being a scientist. Stan also volunteered in a research lab, describing it and his work: "It's a chemical engineering research lab, so I am making a cerium-doped catalyst. So I take terbium nitrate, and I mix it with a certain oxide, and it's a four-day procedure. And I go from raw materials to finished product in four days. And I've been doing that for a while, but before that, I was just babysitting a machine." Based on his research experience, Stan did identify as a scientist: "I do, actually. I feel like a scientist." *Emerging theme*: High-performing students felt being a scientist demanded more experiences with and applications of the physics content.

Chloe noted that some people in class may identify as a scientist: "There's definitely people who identify more, I think. Just 'cause I feel like…they grasp the knowledge easier and stuff." However, because she struggled with the course materials, she agreed that she felt more like a student learning physics. She had not investigated any research opportunities but had planned to do so within the next year: "I haven't really looked into any of that yet. But definitely I think next year, I didn't go to Career Showcase or anything this year. But next year I'm gonna get my resume fixed, go to Career Showcase. I definitely wanna do some internship over the summer, next summer." To her, being a scientist related to a career, where the experience would be facilitated within an internship. Rather than looking for external research opportunities, Leo identified that research opportunities became available with persistence in the physics curriculum: "If you're a physics major and you keep going, the class sizes get smaller. But I feel like that with this many kids, they don't offer anything." When asked whether he felt like a scientist, Leo replied, "No. I feel like a student." *Emerging themes*: (a) Average-performing students felt being a scientist was a future activity that included more initiative on their part and experiences like an internship or more advanced physics classes, and (b) being a scientist demands a "keep-going" attitude.

Isaac expressed how he was "far from [being] a scientist" and felt more "clueless at times." He explained, "Yeah, especially doing physics. A lot of times, I have no clue what I'm doing. And also, when he's explaining the concepts and how it relates to the real-world scenarios, I don't really see it." Similar to Isaac, Rachelle did not identify as a scientist and concerned herself with becoming familiar with physics concepts first:

> I'm not there yet. Because even though I'm starting to understand it, I'm still trying to figure out 'cause even though I see, for some of these questions, how it applies to life, I really want to feel like a physicist that sees….I wanna look at a car and be like, 'Oh, that's—.' Like think of the hills, and think of centripetal acceleration or exactly what we're learning in physics, but I just can't do that.

She characterized a scientist as one able to recall the information specific to his or her field, who developed scientific vocabulary and had an intrinsic understanding of science as seen in the real world. *Emerging themes*: (a) Low-performing students felt far from being a scientist, and (b) being a scientist demands that students understand basic concepts first.

Responses from BL4AL as indications of students' motivation, confidence, science learning, and identification as a scientist

After taking PHY 2048, 18.4% of 228 students strongly agreed they would continue in the sciences because of the course, 39% agreed, 27.6% were neutral, 11.9% disagreed, and 2.6% strongly disagreed. Excluding PHY 2048, 1.8% of students had taken no science course, 61% had taken one to two science courses, 23.7% had taken three to four courses, and 13.6% had taken five or more science courses. None of the students predicted that they would earn a C- or below in the course, while 81.1% predicted they would earn between an A+ to B letter grade in the course.

Table 4-5. Percentage of self-predicted grades in PHY 2048

Letter Grade	Frequency	Percentage
A+	14	6.1
A	66	28.9
A-	34	14.9
B+	32	14.0
B	39	17.1
B-	23	10.1
C+	13	5.3
C	8	3.5
Total	233	100

In order to convey the students' levels of motivation, confidence, science learning, and identification as a scientist for traditional or nontraditional learning methods, Table 4-6 describes the mean of the aggregate scores and the average standard deviation of each dimension and learning method. The student responses were on a five-point Likert scale from 1 Strongly Disagree to 5 Strongly Agree.

Table 4-6. Mean of aggregate scores and average standard deviation for each of the four persistence dimensions for traditional or nontraditional learning methods in PHY 2048

Variable	*M*	*SD*
Motivation—traditional learning methods	2.47	1.02
Motivation—nontraditional learning methods	2.57	1.07
Confidence—traditional learning methods	2.45	1.03
Confidence—nontraditional learning methods	2.55	1.08
Science learning—traditional learning methods	2.35	0.96
Science learning—nontraditional learning methods	2.50	1.03
Identification as a scientist—traditional learning methods	2.58	1.05
Identification as a scientist—nontraditional learning methods	2.68	1.09

Table 4-7 shows the results of the multiple linear regression, in which the students' averaged scores under each of the eight categories (e.g., motivation—nontraditional learning methods and confidence—traditional learning methods) became predictors to the students' responses to whether the course motivated them to continue in the sciences (i.e., Likert scale response to "I am more motivated to study the sciences after taking this course"). A significant regression equation was found ($F(8, 218) = 7.69$, $p < .01$, $f^2 = .28$); with an adjusted R^2 of .19, indicating 19% of the variance could be explained by the model.

Table 4-7. Summary of multiple linear regression analysis for student persistence predicted by the average of student scores for traditional and nontraditional learning methods in PHY 2048

Variable	Course influence for student persistence β	SE B	*p*
Motivation—traditional learning methods	.21	.14	.02*
Motivation—nontraditional learning methods	-.07	.15	.52
Confidence—traditional learning methods	.20	.14	.04*
Confidence—nontraditional learning methods	-.17	.15	.14
Science learning—traditional learning methods	.01	.18	.95
Science learning—nontraditional learning methods	.22	.16	.06
Identification as a scientist—traditional learning methods	.06	.13	.52
Identification as a scientist—nontraditional learning methods	.10	.13	.32

*$p < .05$

The coefficients with significant p-values were motivation—traditional learning methods and confidence—traditional learning methods. When the other independent variables were fixed, each unit increase of the average score for student motivation through traditional learning methods increased the students' indication that the course influenced their persistence in the sciences by .21. When other independent variables except confidence—traditional learning methods were fixed, the unit increase of the average score for student confidence through traditional learning methods also increased the students' indication that the course influenced their persistence in the sciences—in this case by .20.

Case Study Report for CHM 2046: General Chemistry 2

The course was a three-credit, 16-week course, which required 700 students to attend one hour of lecture on Mondays, Wednesdays, and Fridays or two hours of lecture on Tuesdays and one hour on Thursday, as well as one hour of discussion during the week. The class taught on Tuesdays and Thursdays had different requirements than the three-day version. The researcher chose to study the three-day class. CHM 2046 was the second in the two-term sequence of General Chemistry. There was one main instructor who oversaw the course and one graduate and two undergraduate teaching assistants who oversaw the discussion. Students were highly recommended to register for a one-credit, three-hour lab in the same semester they were taking the course.

In the course syllabus the instructor clarified the expectations for class demeanor in that students should attend class on time, not disrupt class with talking or cell phone noises, and leave when dismissed. The instructor also stated: "Emails are for administrative purposes only, and not for distance-instruction. All academic inquiries must be made during office hours or before/after lectures (if time permits). If this is not possible, visit the Chemistry Learning Center...." Nevertheless, components of the course had begun to move to the online environment. Canvas™ housed many of the course materials, including lecture videos, files, and class announcements—class announcements that before would have only been accessible to students in class. The course used Pearson© Mastering Chemistry for students to complete their homework, and the students answered clicker questions during class through LearningCatalytics™. Ten percent of the final course grade was based on the online homework and in-class clicker questions.

Addressing Proposition 1: Blended Learning Affordances Enable or Constrain Active Learning

Instructor's course design decisions as a baseline for the influence of blended learning on active learning

The CHM 2046 instructor, Eva Petrov, was hired by the university to be a lecturer for the introductory science courses. With a Ph.D. in chemistry from Princeton University in 2013, Petrov chose to focus on teaching as a career path: "In grad school, I loved teaching. I hated research." In her four years at the university, people recognized her as a good teacher—being chosen as one of the top five university instructors by a magazine not associated with the university and on RateMyProfessor.com© having a 4.8 rating with 98% of 144 respondents say they would take her course again.

In the interview with Petrov, she outlined that her teaching strategy consisted of: (a) preparing student for class by providing them instructor-created videos or YouTube© videos; (b) assigning Pearson© Mastering Chemistry questions to students to reinforce understanding from the videos; (c) starting the lecture with a graded clicker question via Learning Catalytics© that reflected what was asked in the online homework; (d) facilitating a lecture in which students could participate in discussions; (e) assigning more graded clicker questions as opportunities for students to practice the information being shared in class; (f) creating worksheets for students to further practice; (g) requiring students to attend a discussion class in which student can work on, ask questions, and turn in the worksheets; and (h) testing student knowledge with an exam.

Rather than assigning the traditional textbook readings, Petrov chose specific videos for students to watch before class:

> I have a recommended book. I tell them they can get any book they want, 'cause I know the students don't read. That's why I partially assign the YouTube© videos, 'cause I think that with a video, I know they will. Especially if I assign the correct video, I know exactly what they're getting, I guess. And I have a pre-class sort of homework assignment, and so I know they have to be responsible for that particular content. I think with a book, a student might read the same page in a book and get a lot of different things out of it.

In addition to using the videos to highlight information for students, Petrov also considered the videos as a way to have the students be at the same level of understanding before a lecture:

> And they can choose, I guess, to not watch the video. They can choose to just answer the pre-class homework assignment, if they already know it. I see it more [that] my pre-class assignments are really just getting students to the same level 'cause we have a lot of students that come in with AP credit and they've done it all so it's easy to them. But I have students who've done no chemistry or they're just really slow learners, or for whatever reasons they have a very poor background. And so I'm just trying to get those lower students up to having the same sort of level as maybe the high students.

In the course workflow, after the outside-of-class preparation the students were tested with clicker questions at the beginning of each lecture. Petrov explained her view of the clicker questions: “And then I assess them with a clicker question as soon as they come in…. To make sure they've done it, 'cause, you know, you have to motivate students, incentivize things for students.” Students also earned points for the activity. After the clicker questions, Petrov continued with lecture for about 300 students, which teaching that many students was not a daunting task for her: “No, I actually don't mind. I think with the 300, you have a good energy in the classroom, because everybody's usually awake. There's a lot more people that can help foster conversation with.”

Petrov approached the lecture as an opportunity to have conversations with students who may not talk to her individually before or after class or during office hours. She expected students to answer questions, so she would “stare them down” and be willing to wait two minutes until someone would “break the silence” rather than answer her own questions.

To help with visualizing molecules, interactions, or other information, Petrov used animations and other online resources:

> In class, I tend to use simulations more, rather than demonstrations, 'cause I think a lot of chemistry cannot be seen, 'cause molecules are tiny. And so, I like simulations, personally. It's kind of like an animation that we explore. There's a lot of resources out there on the internet, which I love….so we can explore what molecules look like, and how they act. And sometimes I ask students, predict things.

For the post-class online homework, the instructor did not depend on the publisher’s organization of problem-solving questions. Instead she reviewed the questions according to what would be on the exams: “I selectively choose homework assignments from there. The way I have it through Pearson©, I have access to all of their textbooks, and so I just assign problems between a bunch of them that I think are most helpful for them to study for the exams.”

During the interview, Petrov did not use the terms “blended learning” and “active learning.” However, she identified and described both as they are presented in academic literature. Toward the beginning of the interview, when talking about BL, she did mention that she thought only 10% of her course was online and the rest FTF. Although 10% of the students' grade is scores from the online homework and in-class clicker questions, more than 10% of the students’ experiences related to nontraditional learning methods like the online homework, experiences in the LMS, and online videos. Table 4-8 represents the BL affordances the instructor used in the course for AL.

Table 4-8. CHM 2046 instructor's vision of the relationship of BL affordances for AL

BL affordance	How BL	How AL	Constraint/ enablement
	Traditional learning method		
FTF lecture	FTF, synchronous, multimedia, high human/new technology	Talking and listening plus room space and knowledgeable speaker feed into taking notes/problem solving	Enablement
Simulations/animations/ models	FTF, synchronous, multimedia, high human/new technology	Watching and listening and knowledgeable other feed into taking notes	Enablement
Office hours	FTF, synchronous, text heavy, high human/low technology	Talking and listening and knowledgeable other feed into discussion	Enablement
FTF discussion class	FTF, synchronous, text only, high human/no new technology	Reflecting and worksheet feed into problem solving	Enablement
FTF exam	FTF, synchronous, text only, low human/no new technology	Reflecting and exam feed into problem solving	Enablement

Table 4-8. Continued

BL affordance	How BL	How AL	Constraint/ enablement
		Nontraditional learning method	
Pre-class videos	Online, asynchronous, multimedia, low human/new technology	Listening and reflecting and educational video feed into problem solving	Enablement
In-class clicker questions	FTF, synchronous, multimedia, high human/new technology	Reflecting and teaching technology feed into problem solving	Enablement
Online homework	Online, asynchronous, text only, low human/new technology	Reflecting and homework assignment feed into problem solving/applying information	Enablement
LMS	Online, asynchronous, multimedia, medium human/high new technology	Reading and reflecting and learning technology feed into discussion	Enablement

Perspective of high-performing students on the influence of blended learning affordances for active learning

High-performing students had a letter grade of a B+ or above during the time of the interview. Phoebe, a freshman in applied physiology and kinesiology who wanted ultimately to be a physician assistant, took the course as part of her education track. She chose to take Petrov's course because she felt like she learned better with Petrov's lectures. The previous semester, when Phoebe was in another instructor's section of General Chemistry 1, she attended Petrov's lectures in addition to the lectures with her instructor. Phoebe did not think the content was too difficult, so she was unsure why she could not earn As on the assignments. Cindy was a freshman majoring in pharmacy. In general, her experience in the course had been positive: “So I think Doctor [Petrov]'s structure is really helpful for us to understand the math concepts and the process.” In the interview she explained more about her learning experiences in the course rather than about herself.

Rather than following the prescribed strategy, Phoebe decided that the pre-class videos were unnecessary for her. She took the following steps: “Before the exams, I don't watch the pre-class videos because usually the concept that is discussed in the pre-class videos, she goes, she discusses the big points from the pre-class video and then goes more into depth in it in the beginning of the lecture. So that usually is sufficient.” *Emerging theme*: Pre-class videos can be redundant to information presented at the beginning of lectures.

In lecture Phoebe described it as a “conversation” rather than the typical lecture. Cindy described the clicker questions as “fun” since it encouraged discussion among her peers, and, for questions that had low student performance, the instructor would review each step to solving the question. She thought the in-class clicker questions facilitated small group work, problem solving, and opportunities for trial and error:

> Well, my Chem 1 professor, I did not like him too much, because he wasn't very interactive, in my opinion, whereas Doctor [Petrov] has these clicker questions, whereas my first chemistry professor didn't really have that. It didn't give us an opportunity for trial and error, for our logic in chemistry problems. So it just didn't help how he was just teaching. He was just like talking about concepts, and not really giving us the opportunity to attempt at these problems…. During clicker questions, we're all talking collectively, "Oh, how did you do that? What did you get for that?"

The models used during lecture helped Phoebe to visualize the concepts for the exam:

> Well, just trying to visualize an octahedral structure was really difficult for me. And when I was in the exam, I'm the kind of person that brings the seven pencils and everything, and I had all my stuff out. And I was having a really hard time visualizing the structure, and I tried to think back to the lecture and what she had [with the model], and then I started using my pencils to make a molecule.

Emerging themes: (a) In-class clicker questions enable collaborative problem solving, and (b) lectures using models help students to visualize content.

Cindy had indicated that the homework questions were helpful, but she was confused about the feedback due to the grading being inconsistent: “I think it's pretty good. It gives us multiple tries, and [the instructor] is very really nice on the penalizing part, where if you have like five choices, each time you select an incorrect answer, it'll take it off points…but in the homework sometimes it doesn't penalize you, sometimes it does.” Phoebe valued the online homework but indicated that the questions did not demand as much critical thinking as the exams:

> I think you need to do the homework, the pre-class, you need to watch the video. Because I know a lot of people don't watch the videos and then they don't understand the clicker question in the very beginning of class and then they're confused the rest of class and I'm like, "If you would've built your foundation last night, you would've known it." So that's really important, I think. And then doing the Mastering Chem, even though the questions aren't the best for the exams, they do reinforce the material you learned in class and sometimes expand on it.

Nevertheless, both students completed the online homework right after the lecture so that they could immediately apply their understanding of the material. *Emerging themes*: (a) Online homework provides conflicting feedback about students’ understanding, and (b) online homework questions reinforce content in lectures but not in exams.

Phoebe argued that the exam constrained the learning process for problem solving:

> I feel like I know what I'm doing for the most part in Chem 2, and then I feel like her questions are very tricky. So, I get to the exam and a lot of them are very familiar because her practice exams do give you that exposure, but the exams I feel like some of the wording is a little bit tricky, some of the answer choices are very close.

Cindy did not find the exam to be too easy or too difficult. Both students did not attend office hours; Cindy had time conflicts with office hours and had heard “it’s very crowded.” Nevertheless, both utilized the LMS to access the recorded lecture videos, re-watch them, and review the clicker questions—Cindy retook all her notes while watching the videos. The LMS also housed practice exams, which Cindy found to be more helpful than the online homework because they were more comparable to the exam worth points. Related to the discussion class, the worksheet was available the night before discussion, so students could review the worksheet ahead of time and complete the night before or during class. *Emerging themes*: (a) Exams introduce problems that need to be solved in ways unfamiliar to the students, (b) hearing about crowded office hours deters students from attending, and (c) the LMS fosters students’ review of information shared during lectures and before the discussion classes.

In addition to the affordances mentioned by the instructor, the students also pointed out the role of their friends who could assist with chemistry problems. When struggling outside of class and particularly before exam time they could work with their friends. Cindy also used Study Edge© as a check that she understood all the necessary concepts: “I use [Study Edge©’s] problems that they give us. And they also give, they also have chapter reviews, which I do watch, and exam reviews as well. So, I do set aside some time to watch those just in case like if I'm not familiar with the concept. So, sometimes they'll explain it or I'm just doing math problems and they do it out for you and that kind of thing.” While studying at the library, she also noted that Study Edge©

tutors would be available within a certain area of one of the libraries and assist anyone with questions. On her own Phoebe used Google©, Khan Academy©, and YouTube© videos (other than the ones the instructor had recommended) to enable her to better problem solve: “I mean if I don't understand the concept, I'll look up a video, like the Khan Academy©.” *Emerging themes*: (a) Study Edge© provides a final check of student understanding before the exams, and (b) the search for online resources develops students’ metacognitive awareness.

Table 4-9. Constraints and enablements of BL affordances for AL based on CHM 2046 high-performing students’ perceptions

BL affordance	Phoebe	Cindy
	Traditional learning method	
FTF lecture	Enablement	Enablement
Simulations/animations/ models	Enablement	N/A
Office hours	N/A	N/A
FTF discussion class	Enablement	Enablement
FTF exam	Constraint	Enablement
	Nontraditional learning method	
Pre-class videos	N/A	Enablement
In-class clicker questions	Enablement	Enablement
Online homework	Constraint	Enablement
LMS	Enablement	Enablement
	Additional learning method	
Friends	Enablement	Enablement
Study Edge©	N/A	Enablement
Google©	Enablement	N/A
YouTube©	Enablement	N/A
Khan Academy©	Enablement	N/A

Perspective of average-performing students on the influence of blended learning affordances for active learning

Average-performing students had letter grades within the range of a C+ to a B. Matt was a junior majoring in mechanical engineering yet on a pre-health track. He explained his career path, “I'm not really focused on doing mechanical. I'm more focused on pre-health, but I wanna have an undergrad that I can fall back on or just in case anything happens, as opposed to just having a degree in biology or something like that.” He had taken the General Chemistry 1 course with Petrov as well. Joseph was a junior in psychology who had been a neuroscience major, which was why he was enrolled in the course. He stayed because the course was “interesting.”

Both students watch the videos but do not spend that much time with them—with Joseph commenting, “Normally, [the instructor] has a video link to the pre-class question, so I watch the video to get the concept and then do the question. And that is like, ‘This is what we're gonna learn about today.’ I guess it's good priming stimulus.” The homework question were straightforward for Joseph, but if there were any questions, the homework had built-in guides to problem solving:

> And sometimes they also have hints on the questions where you can click on it and it will guide you through, not directly to the answer. You still have to calculate everything, but it shows you this is what you need to do, basically. And I think that's probably one of the more helpful features because when you're sitting at home and don't know what you're doing, being able to click something that says ‘This is how you do this’ is invaluable.

However, he was frustrated when he understood a concept, but the answer had to be inputted in a specific manner and points were deducted: “If it weren't for a grade, it wouldn't be nearly as frustrating. Like if I got the points just for trying the rigidity wouldn't bother me nearly as much because I would at least be getting a practice and I would have some frame of reference as to how much I get what's going on. But whenever you're graded for something, it just takes all the fun out of it." Contrasting Joseph's sentiment, Matt believed the questions were not as helpful for the level of problem solving required on the exam: "I think the homework is reasonable, I think it does help to understand the concepts. I would like, considering how much conceptual stuff there is on the test, it would be nice if more homework was conceptual, more conceptual problems, because I feel like a large majority of the homework is math-related, but it's not the math that's usually on the test." *Emerging themes*: (a) Pre-class videos are good brain-priming stimuli, (b) online homework can be confusing because inputting information is also assessed, and (c) online homework does not support conceptual understanding.

Additionally, Matt shared a stronger concern about the lectures: "I feel like it's hard for me to learn in that environment where it's just so spacious. And the other thing is I'm not really an auditory learner. Like I said, I have to write everything down. I take notes during her lectures, but it's almost hard for me to just retain something by listening to it." Furthermore, Matt believed that retaining information in lecture was most important to doing well on the exam:

> We'll go over the general idea in class and then when we go and we do the homework, it'll be a little bit more in depth. And then as you get to the last few problems of the homework, that's where it's really the hard problems that you're gonna be looking at close to the exam. And then I feel like even those problems, the harder ones on the homework, aren't the ones that are on the exam. It's like one step past that. So the classes are harder because I feel like there's more expected out of you and you definitely have to retain more.

Joseph did not feel as much pressure in lecture as Matt, but more simply addressed that attending the lecture was one of his responsibilities. In his experience, participating in lecture was a responsibility: “I know as students it just slows the progress of the course if we don't answer the questions.” Both respected the instructor as a good lecturer, and Joseph highlighted a good lecturer facilitates good lectures: “The lecturer makes or breaks the class. Doctor [Petrov] makes it a good lecture to go to. She's engaging. I think she does a good job. I don't know if this is what information you're looking for, but Doctor [Petrov] is also better looking a lot of professors.” *Emerging themes*: (a) Good lectures target multiple senses, (b) how much lecture information to be retained should be clarified, (c) more ways to encourage student participation in lectures should be considered, and (d) the person of the lecturer drives the perceptions of lectures.

Regarding the clicker questions in lecture, both agreed it was a “good experience,” but Joseph experienced some frustration due to technical issues, causing him to lose points. He did acknowledge the opportunity to work with other students and teaching assistants to obtain answers to the clicker questions: “I think it helps because then Doctor [Petrov] knows if everyone's getting what she's saying or if it's all going over our heads. It's not like it's particularly enjoyable, but she lets us work with other students and we can ask the graduate students walking around to help us out.” Joseph also completed the worksheet during the discussion class so that he could work out problems with students and teaching assistants; however, Matt did not mention any experience related to the discussion class. *Emerging theme*: Similar to the theme with the high-performing group, in-class clicker questions and worksheet assignments can facilitate small group problem solving.

Outside of the required class times, the students did not utilize office hours. Matt had attempted to attend office hours with Petrov in General Chemistry 1 but was deterred from attending again: “I almost think it's a fire hazard, 'cause there's like probably 18 people in Korolev's office, if you've seen it. I think it's nice that they had the office hours, but... I don't know, maybe it's just, I don't wanna go because there's just so many people, but most of the times, I can figure out what I have a problem with on my own.” Joseph echoed the sentiment, indicating he went to office hours two times but determined it was better for him to try solving problems on his own. *Emerging theme:* Similar to theme with the high-performing group, the large number of students in office hours prevents students from attending.

During the exams, Joseph said the exams were “fair,” but did mention his grade was highly affected because he had slept through half the time for one of the exams. Matt expressed a constraint in his learning due to the exams: “I think it's hard because of the stress of the exams. That makes it a lot harder because they're worth so many points.” Nevertheless, he was encouraged to see that some students earned a 100% on the exams, which motivated him to know it was possible to do well on them. Matt was enabled to practice more with the resources housed in the LMS, while Joseph did not say anything about his experiences with the LMS. *Emerging themes*: (a) The exam is a heavy-weighted, (b) mysterious assignment that stresses students, and, similar to the theme with the high-performing group, (c) the LMS facilitates unrestricted practice of problem solving.

In addition to the instructor-prepared BL affordances, the students also subscribed to Study Edge©. Joseph watched the general videos and the exam review ones, explaining that he used Study Edge© because "it's the most condensed information possible so that makes it a lot easier for exam preparation and such." Matt watched the chapter reviews and attended the FTF exam reviews, and reviewing the Study Edge© practice questions helped to answer general and homework questions. In order to practice problem solving on his own, Joseph took the initiative to find online resources on his own:

> If I'm trying to understand how to do something, I guess I'll look up what that thing is either in Google© or on YouTube©. And there's almost always a YouTube© video of someone explaining how to do it or just some page on Google©. I'm not looking for any specific website….Whatever the first thing recommends, I assume is the most successful, so like a natural selection. Or if I know a friend of mine has taken this course before they might recommend a YouTube© series of a guy who does the lectures to help out as well.

Emerging themes: (a) Study Edge© shares testable knowledge with students in most condensed way, and, similar to the theme with the high-performing group, (b) the selection of online resources develops students' metacognitive awareness.

Table 4-10. Constraints and enablements of BL affordances for AL based on CHM 2046 high-performing students' and average-performing students' perceptions

BL affordance	Phoebe	Cindy	Joseph	Matt
	Traditional learning method			
FTF lecture	Enablement	Enablement	Enablement	Constraint
Simulations/ animations/ models	Enablement	N/A	N/A	N/A
Office hours	N/A	N/A	N/A	N/A
FTF discussion class	Enablement	Enablement	Enablement	Enablement
FTF exam	Constraint	Enablement	Constraint	Constraint
	Nontraditional learning method			
Pre-class videos	N/A	Enablement	Enablement	Enablement
In-class clicker questions	Enablement	Enablement	Enablement	Enablement
Online homework	Constraint	Enablement	Enablement	Enablement
LMS	Enablement	Enablement	N/A	Enablement

Table 4-10. Continued

BL affordance	Phoebe	Cindy	Joseph	Matt
		Additional learning method		
Friends	Enablement	Enablement	N/A	N/A
Study Edge©	N/A	Enablement	Enablement	Enablement
Google©	Enablement	N/A	Enablement	N/A
YouTube©	Enablement	N/A	Enablement	N/A
Khan Academy©	Enablement	N/A	N/A	N/A

Perspective of low-performing students on the influence of blended learning affordances for active learning

At the time of the interview, the low-performing students had letter grades a C or below. Monica was a sophomore in advertising whose ultimate goal was to become a physician assistant. Although the course was not required for her advertising major, it was for those on track to be physician assistant: “I felt like if I were to have a circumstance that makes me not go to [physician assistant] school any more, I don't want to be left teaching biology or teaching chemistry. Advertising is something that I would love to have a career in also.” Millie was a sophomore entomology major, who had to take General Chemistry 1 twice. She still struggled with large courses because she did not have them in high school: “It's hard for me to pay attention in big classes. I guess they were harder my first year because I didn't know how to learn in college. And now I know a little better how to learn in college. But it's still really hard because I want to a super small high school.”

Monica identified the instructor’s strategy to have students watch the pre-class videos, answer online homework questions, and start class with a similar question to the homework. Millie said the pre-class videos “primes your brain to [be] ready to learn.” Both students struggled with the homework questions though. Monica discussed the struggle of answering the questions being “tedious” and frustrating with the system not awarding points for how she inputted her answers: “If you have the equation right, but you missed a parenthesis…it takes away [points]. You can have the right formula, but if Mastering Chem doesn't have any specific format, then it's frustrating. It's never made a huge difference in my grade, but like you're like, ‘Seriously?’" Millie struggled with the homework as well:

> I'm not doing so great in that. It's just such a burden and it's so many questions. If you put it in wrong, then you get it wrong and it's just like I don't have a great homework grade right now….I think it's mostly the software and the fact that there's so many questions. Usually there's six or seven, but then each one has three or four parts, so it really adds up.

Emerging themes: (a) The online homework stonewalls students’ problem solving if students cannot solve all subquestions. Similar to the themes in the average-performing group, (b) the pre-class videos primed the brain for learning in the lectures, and (c) online homework can be confusing because inputting information is also assessed.

Both students related to the instructor during lectures. Millie indicated a younger lecturer was able to better identify with undergraduate students: “I feel a lot better in Chem 2 than I did in Chem 1. A lot of it is just like, [Petrov's] a great professor. She cares about us, I think. Also, helps that she's young, honestly. She's more relatable to us. I've definitely been stuck in those classes with those cranky old man professors that just won't shut up.” She also enjoyed the style of the lecture being more of a conversation rather than traditional lecture, making a not “silent class.” Although Monica liked the lectures, they did not help her to problem solve on her own: “Well, the most frustrating thing is that by the end of the lecture, I feel like I did understand it, and then when it comes down to it, I don't. Or maybe, I thought I did and my explanation was not right.” Monica had also noted that the instructor did not waiver to activate the students’ senses and to encourage their participation in class: “She'll make us do jumping jacks in the middle of class.” *Emerging themes*: (a) The lecture encourages problem solving in a more conversational environment, and (b) the lecture is insufficient to help students solve problems on their own. Similar to the themes in the other groups, (c) the lecture is influenced by the person of the lecturer.

Thus, for Monica, the in-class clicker questions were stressful because she needed to answer the questions within a short time. For Millie she favorited the clicker questions:

> They go with what she told you. They relate directly to whatever you just took notes on and they make you think critically about it. I feel like if you have to figure something out on your own the first time, you're a lot more likely to remember it the second time. I feel like she'll give you an example and then the problems she gives you is not gonna be exactly the same as the example because she wants you to be able to think about it, and I think that's really helpful.

Both students did appreciate the models and simulations the instructor used to help visualize concepts. *Emerging themes*: The in-class clicker questions constrain problem solving with increased stress due to a limited amount of time, and the in-class clicker questions enable students to practice a concept in a variety of scenarios.

Outside of lecture, the students found the discussion class to be supportive. Although stressed in lecture, Monica found working with teaching assistants and having more time to complete the worksheets enabled her to focus time and energy on solving problems with which she struggled: “The way [Petrov] has [discussion] is like, ‘Hey, you may not get all of them right, but I'm gonna give you more time beforehand so that you can get the ones that you know right off the bat, get those out of the way so we can get to your discussion, the only questions you have are the ones that you really need to ask.’” In the discussion class, Millie was particularly enabled to do the work by one of the undergraduate teaching assistants: “It's really nice to have those undergrad TAs because they literally took the class.” *Emerging themes*: (a) Discussion classes allow students to target areas of weakness, and (b) classes pair students and mentors.

Although Millie did not attend office hours, Monica attended office hours to supplement her lecture experience: “[In lecture I’m] very much absorbing because I don't know what's going on most of the time, but then I go to [the instructor’s] office hours three out of the five days. And that's where I ask every single nitpicky question that I could think of.” She described the office hour experience as:

> I'm never one on one with her though. That's the thing. So it's either me and two other or three other people, or me and 15 other people. It's like, she has people in the hallway, and on the floor and in six and seven chairs, it's packed. Bless her soul. She literally just goes in a circle and answers people's questions for three hours straight. And so, I'll [be] boing into office hours [with] questions, and then while I'm waiting for her to get to me, I'm doing more questions. And then, she usually will take two or three questions at a time and then move on to the next person. So I'll spend maybe five to eight minutes on her, and then she'll move onto the next person.

Emerging themes: (a) Office hours provide and facilitate students’ mentorship, and (b) in large courses students need persistence to attend office hours.

Both did not share much about the exam itself; however, Monica did mention how the exam enables her to problem solve rather than just memorize information: “Because if I get to the exam, it's like, ‘Yeah, I can memorize oxidation numbers,’ but then it's like, ‘What happens when it changes?’ That's another part of the question, and I need to know why, and not just memorize, plug and chug.” In preparation for the exam, both also utilized the LMS to access the practice exams. *Emerging theme*: Exams encourage students to know how to manipulate information rather than just memorize information.

In addition to the required and recommended affordances in the course, both students used Study Edge©. Monica used the Facebook© application to watch short videos (about five minutes) targeting the general chemistry topics, and she attended the four-hour exam preparations. Nevertheless, she no longer felt that she could solely rely on Study Edge©:

> I use Study Edge©, the full membership, where you went every week and the exam review, but now, I've tried to supplement that for her office hours, Petrov's. So, instead of going every week to study, I'm going three times a week to office hours. And I feel like that is so much more helpful because, obviously, it's one on one. It's free. And Study Edge© sometimes tries to give you shortcuts, and then when I'm in lecture, they're conflicting, so it confuses me. So I go to the exam review after I've gone through all those weeks of going her way….Like with yesterday, I went to the four-hour exam review.

Millie watched how Study Edge© solved exam questions, and did not rely on it as much as she had in General Chemistry 1:

> [Study Edge©] hasn't been this good 'cause the curriculum did change this semester, and they weren't able to catch up with it, I guess. So I honestly just study off of the materials [Petrov] gives us, and that's worked really well for me so far. The worksheets that we do out of class, I have a really great TA, actually, undergrad TA. She's amazing, very helpful, and so I study off the worksheets. I study off the practice exams because she's the one writing the exam. It doesn't really make sense for me to go to an outside [the] program. The only thing I've used [Study Edge©] for is watching solutions for practice exams 'cause it just makes it easier to not have to go all the way to the tutoring center whatever, but I haven't used it that much this semester. I used to think it was like an end-all, be-all crutch, and now I don't have as much confidence [for Study Edge©].

Emerging themes: (a) Study Edge© confused students with conflicting priorities on what to study, and (b) Study Edge© gave students a false confidence in its ability to help them do well on the exam.

Both also studied with friends. Millie studied with Phoebe (one of the high-performing participants); both did not know that each other had volunteered and had been selected for the study. When alone and close to correctly answering questions after multiple attempts Monica referred to Google©, whereas Millie refers to Google© and YouTube© to help her with the math required to solve the chemistry problems.

Emerging theme: Outside of class students require mentorship.

Table 4-11. Constraints and enablements of BL affordances for AL based on CHM 2046 high-performing students', average-performing students', and low-performing students' perceptions

BL affordance	Phoebe	Cindy	Joseph	Matt	Monica	Millie
			Traditional learning method			
FTF lecture	Enablement	Enablement	Enablement	Constraint	Enablement	Enablement
Simulations/ animations/ models	Enablement	N/A	N/A	N/A	Enablement	Enablement
Office hours	N/A	N/A	N/A	N/A	Enablement	N/A
FTF discussion class	Enablement	Enablement	Enablement	Enablement	Enablement	Enablement
FTF exam	Constraint	Enablement	Constraint	Constraint	Enablement	N/A
			Nontraditional learning method			
Pre-class videos	N/A	Enablement	Enablement	Enablement	Enablement	Enablement
In-class clicker questions	Enablement	Enablement	Enablement	Enablement	Constraint	Enablement
Online homework	Constraint	Enablement	Enablement	Enablement	Constraint	Constraint
LMS	Enablement	Enablement	N/A	Enablement	Enablement	Enablement
			Additional learning method			
Friends	Enablement	Enablement	N/A	N/A	Enablement	Enablement
Study Edge©	N/A	Enablement	Enablement	Enablement	Enablement	Enablement
Google©	Enablement	N/A	Enablement	N/A	Enablement	Enablement
YouTube©	Enablement	N/A	Enablement	N/A	N/A	Enablement
Khan Academy©	Enablement	N/A	N/A	N/A	N/A	N/A

Researcher's review of documentations of blended learning affordances for active learning in PHY 2048

The researcher reviewed the course's documentations, which were found within Canvas™ (see Figure 4-6). The Modules for the course included information like the course syllabus, as well as the worksheets and practices exams and their correct answers.

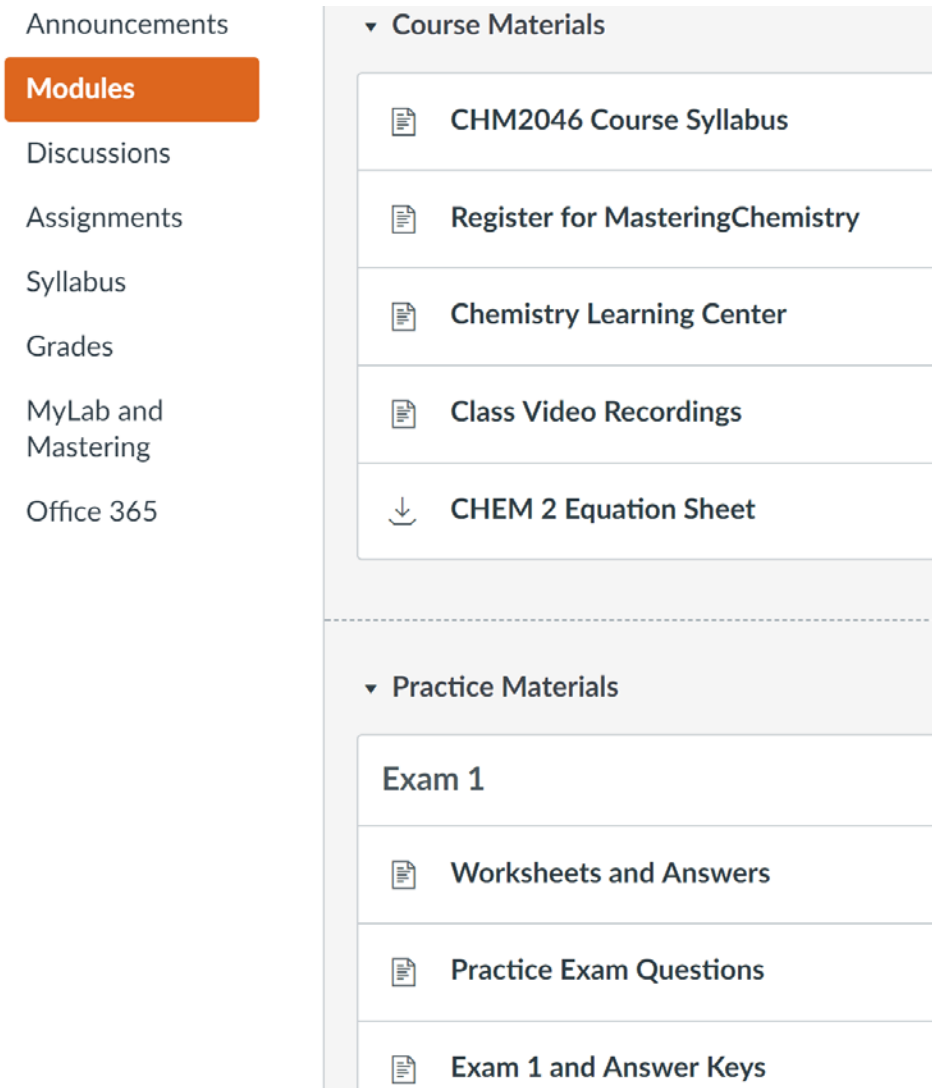

Figure 4-7. Snapshot of CHM 2046 Modules section in LMS with links to course documentations.

Within the course syllabus, the instructor identified BL affordances but did not explain how the affordances influence learning. The closest example to an explanation was the course objectives: “As both a general education requirement and major’s course, CHM2046 serves to teach: the scientific method, skills for problem solving, general chemistry knowledge, and a connection to the principles that govern the natural world.”

The course syllabus discouraged emails, which the instructor explained during the interview that email would be a challenging medium to use when reviewing problem-solving processes with students. Thus, the FTF attendance in lecture and office hours were emphasized for student-instructor interactions. Class video recordings were made available to students for personal review at their leisure. A BL affordance that was available but not mentioned during the interviews was the Chemistry Learning Center, in which graduate teaching assistants provided free tutoring services to students. A professionally created video showing how to find the center was available to students. Discussions classes were weekly and mandatory for students; a completed worksheet submitted during discussion contributed to the students' grade. The description about the exams included only directions when taking the exam rather than the purpose of the exams.

Expectations for the online class environment were outlined in the syllabus as well: "It is your responsibility to check Canvas™ often to make sure that you do not miss important announcements and to ensure that your gradebook is accurate." Within class announcements the instructor communicated what course expectations were, when grades were uploaded, whether edits were made to homework questions, when exam review questions were shared, and where students should take their exams. An example of a course announcement was: "There were some issues on HW 11 Item 8, so the problem was reset and the scores were cleared. If you already completed the homework, you will have to redo the problem since your score was cleared." The commenting feature was turned off for the announcements. Students were also expected to complete online course evaluations in the LMS in order to provide feedback as to how the course could be improved. Pearson© Mastering Chemistry facilitated the online homework. Students logged into the online homework via Canvas™, and the instructor also provided an instructional video on how to register with Pearson© Mastering Chemistry. Figure 4-8 shows the BL affordances and their possible influences for AL. Based on what was noted in the documentations, certain BL affordances enabled AL when paired with other media. For example, students could have better experiences with online homework because an instructional video was added on how to register.

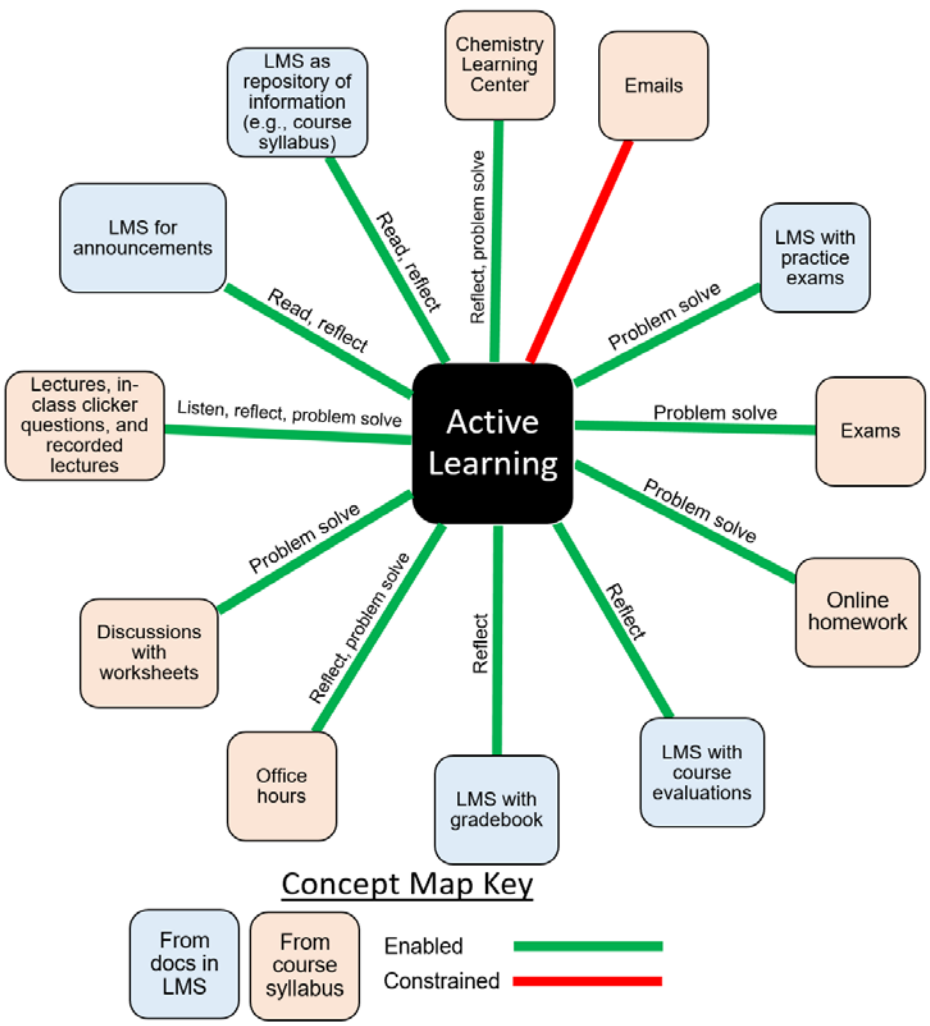

Figure 4-8. Conceptual map of the influence of BL affordances on AL according to the CHM 2046 documentations.

Researcher's observations of blended learning affordances for active learning

Face-to-face learning environments. Similar to the observations made related to PHY 2048, the researcher observed two lectures and one discussion class. Figure 4-9 and Figure 4-10 are university photos showing the setup of the lecture hall and a classroom for discussions.

Figure 4-9. Photo taken in larger CHM 2046 lecture hall (photo obtained with permission from a large public university in the South).

Figure 4-10. Photo taken in a classroom similar to the one in which the observed CHM 2046 discussion class was held (photo obtained with permission from a large public university in the South).

The classroom arrangement also focused on interactions between the instructor and students rather than students with other students. Although students in both types of classrooms, particularly the auditorium with the seats bolted down, could only communicate with other students around them, the teaching assistants walked up and down the aisles of the auditorium in efforts to be more accessible to students. Additionally, within the smaller classroom environment, students were allowed to move and talk to other students or the teaching assistants in the front because the teaching assistants did not lecture but answered questions and checked students' work for correctness.

During the classroom observations, for the first dimension of practice, on average 87% of the class time students had the possibility to talk through the content. The instructor would pause about every five minutes to ask the students a question about the concept or problem she was discussing. During the discussion class, students had the entire time to talk through content with the teaching assistants or other students. Additionally, as the students answered the in-class clicker questions, teaching assistants walked up and down the aisles in the auditorium in case any student wanted to stop them to ask questions. For 80% of the activities students practice higher order thinking skills, while 100% of the exams requires the students to exercise higher order thinking skills. During the lectures the instructor asked the students why questions as she discussed problems with them, while students exercised critical thinking with the worksheets for the discussion class. The instructor reminded students to use prior knowledge about 67% of the activities, and for 93% of the activities the instructor heard students' responses and provide feedback. If students did not respond, the instructor would wait in silence for students to respond, and she provided feedback to the students when they did respond.

For the second dimension of logic development, 80% of activities included problems that required students to use higher order skills (e.g., application, analysis, evaluation, and synthesis), while 67% of activities included a reminder for students to use logic before explaining or defending their answers. In response to the instructor's why questions, the students explained their answers, and the instructor would ask follow-up questions to encourage students to explain their responses in more detail. Before students discussed answers, 73% of the activities allowed them to have time to think before they discussed; in also 73% of the activities did students explain their answers to peers. The students had the opportunities to discuss their answers either in front of the whole class or in small groups. For 27% of the activities did students solve problems without hints from the instructor or the results from clicker questions. In front of the whole class students had the opportunity to explain the logic behind the answer choices during 60% of the activities, and for 53% of activities was the logic behind the correct answer explained by the instructor. However, only in 7% of activities was the logic behind incorrect answers explained.

For the third dimension of accountability, 73% of the activities were worth points, and 53% of activities involved small group work facilitating more student participation. None of the activities included cold or random calls to avoid volunteer bias.

For the fourth dimension of apprehension reduction, students did not receive practice to respond to cold or random calls. The class received praise for 13% of the activities, and individual students received praise for 53% of the activities. The instructor's practice was to acknowledge that an answer was correct or to ask the student to clarify their response before continuing the discussion. At no time did the students receive negative feedback. For 33% of the activities the instructor reminded the students that they did not need to fear mistakes. The instructor praised the students for hard work over ability during 60% of the activities.

Online learning environments. Within the LMS Canvas™ students were able to communicate with the instructor, teaching assistants, and other students mainly through the use of the Discussions feature. Students asked about general chemistry information. For example, a student shared, "On this question, I am having a hard time understanding why part II is correct? Any explanations would be appreciated." Another student empathized and responded, "I got it wrong as well on form B (number 3). The reason is because the H+ ion in solution will spontaneously react with the Pb(s) on the electrode. I was so confused at first too." The first student was able to clarify his understanding by writing: "Thanks for the reply. Given what you said, how is this considered a redox reaction and how would the electrons still flow from the anode electrode to the cathode if they are both breaking down?" A different student was able to practice her knowledge by responding: "It's considered redox because the Ag goes from having no charge to a charge of plus one (oxidation). The loss of the electron then drives the lead to go from a charge of 4+ to 2+ (reduction). In a voltaic cell, electrons will always flow from anode to cathode. Hope this helps!"

In two other instances, students asked about exam or practice exam problems, and other students replied with possible solutions. A student in another discussion post shared his email address and said he was interested in starting or being a part of a study group. Another student wanted to share helpful tips a teaching assistant had provided: "I just wanted to let everybody know that the answer to number 1 on the Exam 1 Review is D (I and III only), not C. I checked with the TAs who made the review, and they said that the answer key had a typo on it. Good luck on your exams!"

Addressing Proposition 2: Relationship between Blended Learning Affordances and Active Learning Encourages or Discourages Student Persistence

Students' perspective related to their motivation, confidence, science learning, and identification as a scientist

Motivation. A high-performing student, Phoebe, shared that the subject matter and instructor motivated her in the course: "I hated chemistry coming into college, and I considered switching to a chem major at the end of last semester. And even the beginning of this semester, I really enjoy the concepts and the material, I love learning about it, Doctor [Petrov] is the best professor I've ever had." However, although she enjoyed chemistry studies, she was deterred from being a chemistry major: “I know it's kinda bad I don't wanna do [Organic Chemistry 2]. I heard that it's such a weed out class that I just—the idea of doing [Organic Chemistry 2] is very difficult to me.” Phoebe had decided to continue on track to being a physician’s assistant, which did not require Organic Chemistry 2. Cindy was also motivated by her interest in the sciences:

> I feel pretty motivated because I'm more a science person in general, so I do like science. I more dread over reading things like articles from my other classes. So I really don't mind doing math problems and chemistry because math makes it easier for me to understand. I just like science. If we think about it, we're all made of cells, and these cells form bigger things like tissues and our bones and our bodies, our brains and how we just move and everything about us. There's something behind it and anatomy. I'm just gonna include anatomy just for a little bit. And anatomy's made me realize everything that we do, everything that happens to us, these diseases, these syndromes and anything, there's an anatomical reason behind that, and it just really amazes me how science is, how it applies to our daily lives.

With her understanding of and enthusiasm for the sciences, Cindy wanted to pursue a pharmacy degree. *Emerging themes*: (a) Attraction to the subject makes course appealing, and (b) the role of the instructor, as seen in lectures, can be to foster an interest in the course.

An average-performing student, Joseph, shared the desire to succeed motivated him, as well as the desire to support the instructor’s efforts: “Besides just wanting to succeed…Doctor [Petrov] is really great, probably her, someone who, really, you can tell enjoys teaching, and you know she doesn't do any research? She just teaches.” For Matt, his long-term goal of being a doctor motivated him to do well in the course. Although he need a 100% on the final exam to earn an A in the course, he knew he could at least earn a B in the course, which kept him in the course: “So right now, I'm at, I think, a B. So I don't know. A little disappointing. Pretty much, I looked at it. I have to get 250 out of 250 points for an A in the class. Last semester, she had two extra credit questions, so I was able to get, I got a 260 out of 270 possible. I think it's doable, but [we'll see]." *Emerging themes*: (a) Combination of career goals and course requirements prevent students from dropping course, and (b) the attainability of passing keeps students in course. Similar to the theme with the high-performing group, (c) the role of the instructor, as seen in lectures, can encourage students to perform well in the course.

A low-performing student, Monica also expressed how being a physician's assistant motivated her to continue and to try to do well in the course:

> I feel like chem is more rewarding 'cause you have to put in a lot of work to understand the concepts. Chem is very exhausting, I feel like, especially my experience this semester. It's been like, 'Oh, why do I even wanna do this anymore?' See, it's more of an end-goal motivation. So I hate what I'm doing right now, but the end goal is to help people later on. So I wouldn't say that that exactly encouraged me towards [being a physician's assistant], but there's a sense of accomplishment once you pass the class.

Despite wanting to quit the course at times, Monica continued with the "end goal" in mind, having experienced the satisfaction one feels after completing an arduous task. Expressing a similar feeling, Millie adored being an entomology major, and taking the course was a requirement for the major:

> I always loved bugs from a very young age, and I came into college and I was the classic 'I'm gonna be a doctor.' And then I realized I'm not gonna be a doctor, I'm gonna be an entomologist 'cause that's what I love….[Chemistry is] a requirement for my major, which I'm on the basic science track, which it sets you up for grad school, basically. So I take one more chemistry class, and then I'll be done with chem….I'm almost done with my big weed-out classes, which is exciting.

Millie addressed CHM 2046 as a "weed-out" course, indicating her expectation that the course purposefully discouraged people from continuing in the sciences. *Emerging* *themes*: (a) The sense of accomplishment influences students to continue in a course. Similar to the theme emerging from the other groups, (b) the “end goal” of being a professional encourages students to remain in courses, and (c) the course being required by an academic track motivates students to pass the course.

Confidence. Because Phoebe “really enjoyed” the course, she felt confident in the course and was able to identify her areas of strength and weakness:

> So, when I'm reviewing my missed questions, I'm always like, "I really understood this concept. Why didn't I get this?" The only question that I didn't understand the concept was the very last question of this previous exam, and…she took a concept that we had learned, and then gave us a little bit more information about it, like, "What would happen if you distorted this orbital?" and then kind of wanted us to infer what would happen and predict. And, it probably was fair in the sense that we did learn the basis of the concept, but it was very different from what I'd seen. I didn't know what to do. So, that was one that I just did not know at all.

Rather than merely trying to grasp the concepts, she exercised higher-order thinking skills to metacognitively assess her knowledge of a concept. Cindy succinctly shared that she did not feel “very confident” but felt “moderately confident” because she was earning an A in the course and told herself, “I can do it. I can do it.” *Emerging themes*: (a) Confident students metacognitively consider strengths and weaknesses as exemplified in their exam responses, and (b) grades reinforce confidence in a course.

Joseph acknowledged that CHM 2046 was “not an easy course,” but he was confident in his understanding of the course materials: “Even having slept through half of that exam, had I done well enough on the third exam, I probably could've [earned a higher grade].” He believed he would have had a higher grade if he had attended the exam on time. Furthermore, he felt adequately confident in the course to select what was “worth” his time:

> I'm constantly weighing how much time I'm going to spend doing something versus how much it's worth. Like studying for an exam, I'll put in as many hours as I have to, 'cause that's the most important. Doing a homework problem online, it's not uncommon that I'll just decide to skip one problem because the whole assignment is three points. One problem is practically nothing. Why waste 15 minutes of my life doing a problem that's worth a tenth of a point?

In contrast to Joseph's confident attitude, Matt was uncertain of his handle on the course materials. Despite practicing with instructor-provided materials and Study Edge© materials, he did not perform as well as he wanted on the exams and did not know why that was the case: “The thing is I thought [my studying] worked for me and then I did bad on the last test, and I dunno if this is just because maybe I'm just tired as we're going through the end of the year, but it just feels like it's just so much harder for me to understand things even though I know the concepts aren't harder.” Thus, the resources Matt had used to help him study before no longer supported him as much as they had.

Emerging themes: (a) Exam grades may not indicate student confidence, (b) students exhibit confidence when they can identify what BL affordances help them to learn, and (c) the use of BL affordances may need to be re-evaluated to bolster student confidence. Similar to the theme with the high-performing group, (d) class grades may influence a student's level of confidence.

Monica did not “know what's going on most of the time;” however, she developed more confidence in her understanding of the material by attending office hours three days a week and asking “every single nitpicky question.” She believed she could improve her grade in the course because she faulted her lower grade due to her attention on being a beauty pageant contestant during the second exam: “I think the second exam was probably just because I wasn't as focused. I was making up explanations for myself, and it wasn't right. But now, I'm feeling a little bit better.” Millie also benefited from finding help within the course. Study Edge© did not change its curriculum when CHM 2046 changed its curriculum, Millie did not want to use Study Edge© as "crutch" any more. She felt that through attending lectures, working on the in-class clicker questions, reviewing the practice exams, and asking her undergraduate teaching assistant questions, she would be able to pass the course: "I have not gotten weeded out yet, and I don't plan on it. Who knows though?" *Emerging theme*: Similar to the theme with the average-performing group, students exhibit confidence when they can identify what BL affordances help them to learn.

Science learning. Although Phoebe has enjoyed learning chemistry with Petrov, she shared that she was not doing as well in General Chemistry 2 than she was in General Chemistry 1:

> I ended up with such a high score in Chem 1 that I thought Chem 2, I'd come in, I heard it was easier. Really thought I would just have to do the same amount of work. I worked very hard in Chem 1, but I thought I would do it in Chem 2, and I would be able to get the same scores. Unfortunately, I've been getting Bs on the exams, so I've been disappointed by that…I really enjoy the concepts and the material. I love learning about it. Doctor [Petrov] is the best professor I've ever had. I just really enjoy it, but I am not doing as well as I thought I would.

Despite working hard by completing the online homework, attending lecture and re-watching the lectures recorded, reviewing clicker questions, studying with another classmates, and finding online resources, Phoebe earned Bs on the exams. The only instructor-recommended step that Phoebe did not take was to watch the pre-class videos. Following the instructor's recommended practices, Cindy had an A in the course at the time of the interview. She highlighted the "trial and error" encouraged by the instructor during problem solving in lectures, and noted, "So I think Dr. Korolev's structure is really helpful for us to understand the math concepts and the process."

Emerging theme: Students are unsure how to identify learning practices to change after they follow prescribed uses of BL affordances.

Driven by a sense to learn, Joseph attended and participated in lectures: "I've [answered questions] literally 10 times in that class now, but I just want to get through the stuff. I just wanna learn here. I don't know why more people don't just answer the questions that professors ask…. I'm very used to the teacher lecturing method of learning." Aside from lectures and discussions, he was selective on which resources to use and primarily relied on finding online resources like YouTube© and Google© as a help and using Study Edge©'s materials: "Yeah, I would say I use [Study Edge©] a lot, I guess. It's the most condensed information possible so that makes it a lot easier for exam preparation and such." Instead of selecting which resources to use, Matt felt obligated to use all the resources to do well in the course, particularly the exams:

> I try to go [to Study Edge©] in person. And then I try to do the practice problems in the back that'll focus on that section. So usually there'll be three reviews and then there'll be the final review. I'll try to go at all of those in person. I'll try to do all the practice problems. Sometimes, for the chapter reviews, I don't end up doing all the practice problems. But for the main review, I usually always end up doing all the packets, or all the problems that are at the back. And then on top of that, I'll do the review that [Petrov] posts and then sometimes I'll do the additional review that's put on by the students. I think it's the student [teaching assistants], they put on that, I'll try to do a few of those problems but that's not really what I focus on. So for me, it's mostly I learn by writing things, so I just try to practice a lot and just get exposed to the problems and it's almost, I don't know if it's the smartest way to study.

Being desperate to do well in the course, he practiced by writing in response to the problems and was unable to credit which BL affordances contributed to his performance in class. *Emerging themes*: (a) Instructor lecturing methods should be explained for more student participation, and (b) not all students know how to purposefully use BL affordances for learning.

Monica approached learning the chemistry content by working as closely with the instructor as possible. She attended the lectures and attempted to “absorb” as much information as she could, although oftentimes she “[doesn’t] know what’s going on most of the time.” She primarily discussed her questions with the instructor and other students during office hours, in which she and the other students waited for the instructor to cycle to them: “I'll be like, ‘Oh, hey, have you done item two already?’ And [other waiting students are] like, ‘Yeah, sure.’ Other times it's like, ‘Yeah, I got it, but I don't know why.’ So when she comes back, we'll both ask her, like, ‘Hey, we kind of know the answer, but we don't know why.’" In Millie’s experience, she “didn't know how to learn in college” and now she knows “a little better how to learn in college,” indicating she found large classes challenging compared to her smaller classes in high school. She explained her responsibilities in the course: “You have to study, you have to pay attention, be present in class, answer their questions, do your homework. I feel like these types of classes, a lot of it is handed to you on a silver platter, so it's like up to you to pay attention.” To learn the material though, she particularly relied on working with the undergraduate teaching assistant and focused on the in-class clicker questions that review a concept just discussed in lecture and “make you think critically about it.” She found online resources like YouTube© and Google© when needed. *Emerging themes*: (a) The BL affordances involving more instructor contact support struggling students, (b) BL affordances encouraging group interactions can also support struggling students, and (c) BL affordances may mitigate confusion among students yet not be used to their full potential.

Identification as a scientist. Phoebe shared that the experiences in the course did not make her feel like a scientist but someone studying science: “I don't know if I would say I feel like a scientist. I feel like a science major. To me, I guess being a science major like I feel like I have an interest in the sciences. I excel in the sciences. I don't mind learning about it. I really enjoy learning about chemistry like I said.” Cindy more clearly demarcated the difference between a scientist and a student:

> I think a scientist, is a different thing because a scientist, they do research. They hypothesize things. They do things. They're not just doing the simple problems. They're doing real life, real-world problems. So I don't think, because a scientist, you can't really be a scientist in chemistry-lecture kind of things. As a student, you can't really be a scientist, I think.

Emerging theme: Students do not connect learning about science to being a scientist.

Because Joseph was planning on being a psychologist, he did not think that scientists would agree he be called one: “I feel like if I say I'm a scientist, all the physicists are gonna be like, ‘Screw you, psychology major.’" However, while he studied in the chemistry lab, he felt like he was a scientist, “applying the method to things.” Matt also mentioned being a scientist meant the application of the knowledge being learned: “So, to actually do what we talk about in the course. In lab, we did make electrolytic cells and stuff like that, but they were on a really small scale. It just, it wasn't as exciting as I thought it was gonna be, and, I don't know, I don't feel more of a scientist. I just feel more of a student, more than anything.” *Emerging themes*: (a) Perception of being a scientist can vary among the sciences, and (b) a course’s lab experiences facilitate student learning rather than the work of a scientist.

At times Monica did feel like a scientist:

> Oh, sometimes, yeah. I feel like I'm not a scientist as in I'm experimenting all the time, but it definitely has changed the way I think, think about like,

> ‘Why?’ For a very basic example, when I'm cooking, how come whenever I put this much baking powder in, the cake rises a little bit? But if I put in a lot, then it can exceed the potential that it needs. It changes the way you think about that.

Monica identified the difference between being a scientist as a profession versus having the mind of a scientist. In her experience, although she did not consider herself a scientist, she had begun to consider the world through a scientific lens. Millie also expressed the differences between being a student versus a scientist: “Sometimes in the lab I really felt like we're doing big girl experiments. I made an electrode. That's crazy. I think really learning concepts—it’s really hard to feel like a scientist. I don't think the purpose of Chem 2 was to make you feel like a scientist, I think it's to make you learn Chem 2.” Although the lab experiences provide exciting experiences and made her feel closer to being a scientist, Millie highlighted that students should maintain their status as such to learn chemistry rather than focus on being scientists. *Emerging themes*: (a) Being a scientist and thinking like one are two different things, and similar to a theme from the average-performing group, (b) lab experiences encourage students to apply their knowledge as scientists would.

Responses from BL4AL as indications of students’ motivation, confidence, science learning, and identification as a scientist

After taking CHM 2046, 30.8% of 302 students strongly agreed they would continue in the sciences because of the course, 38.1% agreed, 20.9% were neutral, 7.9% disagreed, and 2.3% strongly disagreed. Excluding CHM 2046, 0.7% of students had taken no science course, 35.8% had taken one to two science courses, 43.4% had taken three to four courses, and 20.2% had taken five or more science courses. One percent of respondents indicated they would not earn a C or above in the course, while 77.5% predicted they would earn a grade within the range of an A+ to B in the course.

Table 4-12. Percentage of self-predicted grades in CHM 2046

Letter Grade	Frequency	Percentage
A+	25	8.3
A	71	23.5
A-	59	19.5
B+	47	15.6
B	32	10.6
B-	22	7.3
C+	18	6.0
C	25	8.3
C-	1	0.3
< C-	2	0.7
Total	302	100

Table 4-13 describes the mean of the aggregate scores and the average standard deviation of each dimension and learning method. The student responses were on a five-point Likert scale from 1 Strongly Disagree to 5 Strongly Agree.

Table 4-13. Mean of aggregate scores and average standard deviation for each of the four persistence dimensions for traditional or nontraditional learning methods in CHM 2046

Variable	*M*	*SD*
Motivation—traditional learning methods	2.36	1.04
Motivation—nontraditional learning methods	2.55	1.06
Confidence—traditional learning methods	2.33	0.97
Confidence—nontraditional learning methods	2.51	1.02
Science learning—traditional learning methods	2.30	0.96
Science learning—nontraditional learning methods	2.45	1.00
Identification as a scientist—traditional learning methods	2.56	1.07
Identification as a scientist—nontraditional learning methods	2.65	1.07

Table 4-14 shows the results of the multiple linear regression, in which the students' averaged scores under each of the eight categories (e.g., motivation—nontraditional learning methods and confidence—traditional learning methods) became predictors to the students' responses to whether the course motivated them to continue in the sciences (i.e., Likert scale response to "I am more motivated to study the sciences after taking this course"). A significant regression equation was found (F(8, 293) = 6.84, p < .01, f^2 = .19); with an adjusted R^2 of .13, indicating 13% of the variance could be explained by the model.

Table 4-14. Summary of multiple linear regression analysis for student persistence predicted by the average of student scores for traditional and nontraditional learning methods in CHM 2046

	Course influence for student persistence		
Variable	β	SE B	*p*
Motivation—traditional learning methods	.03	.12	.72
Motivation—nontraditional learning methods	.13	.12	.17
Confidence—traditional learning methods	.30	.14	.00*
Confidence—nontraditional learning methods	-.05	.15	.66
Science learning—traditional learning methods	.00	.16	.97
Science learning—nontraditional learning methods	.08	.15	.49
Identification as a scientist—traditional learning methods	.06	.11	.49
Identification as a scientist—nontraditional learning methods	-.07	.12	.42

**p < .05*

Confidence—traditional learning methods was the only significant predictor (positive directionality) of whether students agreed the course influenced them to continue in the sciences. When the other independent variables were fixed, its coefficient indicated that each unit increase of the average score for student confidence through traditional learning methods increased the students' indication that the course influenced their persistence in the sciences by .30.

Cross-Case Analysis

Based on the themes from the individual cases the researcher conducted a cross-case analysis with the purpose to deepen understanding and explanation of BL affordances on AL for student persistence within introductory science courses.

Following Yin’s (2014) replication strategy and Miles and associates’ (2014) recommendations, PHY 2048 was first compared to the conceptual framework in order to identify themes related to the influence of BL affordances on AL; themes from CHM 2046 were then compared to that of PHY 2048—the similar and different results strengthening or weakening the original theory (Miles et al., 2014; Yin, 2014). The themes emerged as students discussed BL affordances that particularly influenced their AL experience. Ultimately, the summary of the comparison produced its own propositions to be compared to the propositions made before the study (Ericksen & Dyer, 2004).

Addressing Proposition 1: Blended Learning Affordances Enable or Constrain Active Learning

The first research question examined the first portion of the study’s conceptual framework—BL either enables or constrains AL (see Figure 4-8). The results from the interviews and the review of documentations primarily identified the BL affordances and whether they enabled or constrained AL. The results from the observations primarily examined evidence of AL from the affordances.

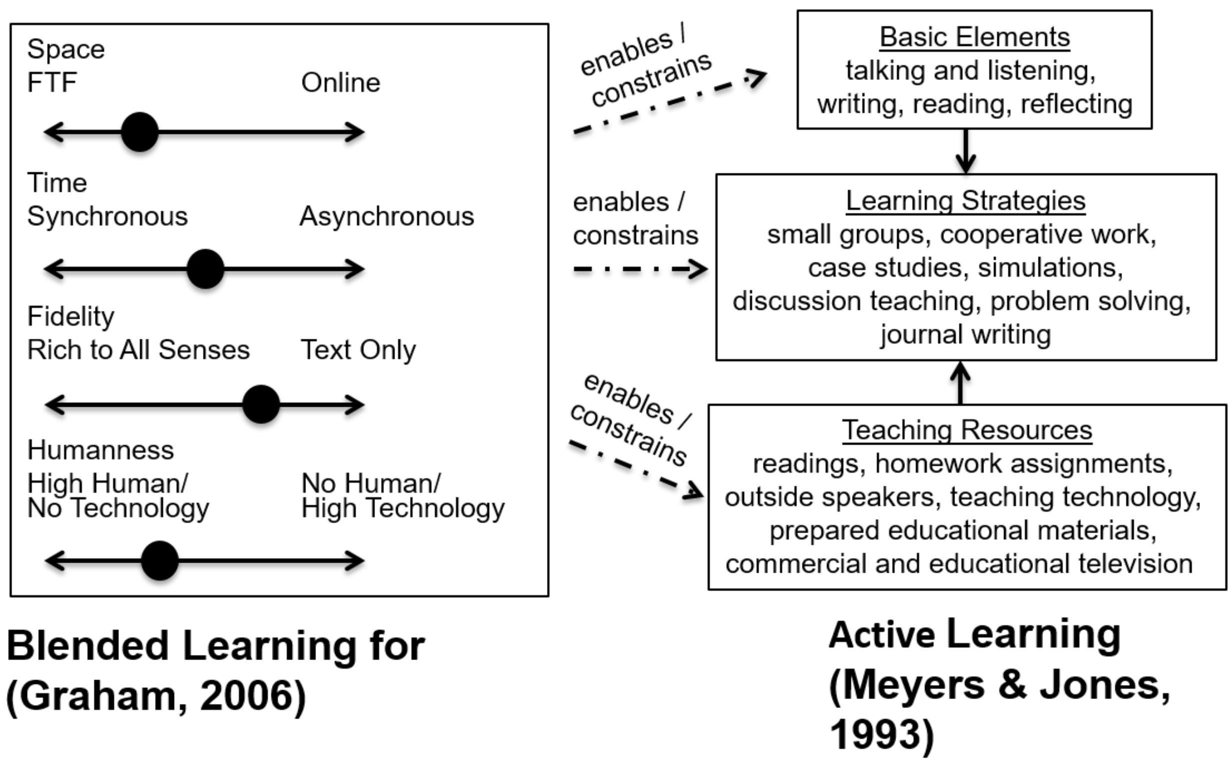

Figure 4-11. First half of the study's conceptual framework focusing on BL affordances enabling or constraining AL.

Students' perspective on the influence of blended learning affordances for active learning

From the interviews with the high-performing, average-performing, and low-performing students, themes among the groups depicted the influence of BL affordances for AL (see Table 4-15). The themes were determined based on lengthier explanations provided for a BL affordance. Thus, if a student only replied that they attended the discussion class, no theme emerged. Related to traditional learning methods, students in all three performance groups in PHY 2048 discussed their experiences with lectures, exams, in-class clicker questions, while students in CHM 2046 discussed their AL experiences with lectures, exams, and office hours. The low-performing students in PHY 2048 did not focus on discussion, while the low-performing in CHM 2046 were the only group that explained their experiences in discussion. The low-performing group in PHY 2048 discussed in-class demonstrations, while the high-performing group in CHM 2046 discussed the in-class models. For the nontraditional learning methods, all three groups were impacted by in-class clicker questions and additional resources, particularly Study Edge©. Students in CHM 2046 discussed online homework, pre-class videos, and additional resources, also emphasizing Study Edge©. There was no separate publisher’s website that was separately identified in the CHM 2046 interviews. Implications of the themes are presented in more detail in Chapter 5: Implications.

Table 4-15. Comparison of themes about blended learning affordances and active learning among high-performing, average-performing, and low-performing groups in PHY 2048 and CHM 2046

BL affordance	PHY 2048	CHM 2046
	Traditional learning methods	
Lectures	High-performing: The lectures are a spectacle, in which students watch and listen to the instructor present physics concepts. Average-performing: Same as high-performing. Low-performing: (a) Lectures can be a place for students to hide, (b) information in lectures not accessible to all students, and (c) lectures do not prepare students to visualize concepts.	High-performing: Students paired their discussion of lectures with simulations / models / animations, online homework, pre-class videos, in-class clicker questions, and LMS. Average-performing: (a) Good lectures target multiple senses, (b) how much lecture information to be retained should be clarified, (c) more ways to encourage student participation in lectures should be considered, and (d) the person of the lecturer drives the perceptions of lectures. Low-performing: (a) The lecture encourages problem solving in a more conversational environment, (b) the lecture is insufficient to help students solve problems on their own, and (c) same as (d) with average-performing.
Discussion	High-performing: (a) The discussion class offers homework support, and (b) the discussion class is only a place to take the quiz. Average-performing: (a) Discussions lack visualizing the problems and (b) same as (b) in high-performing.	Low-performing: (a) Discussion classes allow students to target areas of weakness, and (b) classes pair students and mentors.

Table 4-15. Continued

BL affordance	PHY 2048	CHM 2046
	Traditional learning methods continued	
Exams	High-performing: (a) The exam captures how much the students know, (b) the exam is a mystery to be solved, and (c) the exam creates anxiety. Average-performing: Same as (b) and (c) in high-performing. Low-performing: Student performance in online homework indicates exam performance.	High-performing: Exams introduce problems that need to be solved in ways unfamiliar to the students. Average-performing: The exam is a heavy-weighted, and (b) mysterious assignment that stresses students, and, similar to the theme with the high-performing group. Low-performing: Exams encourage students to know how to manipulate information rather than just memorize information.
Office hours	Average-performing: Office hours were inconvenient to students. Low-performing: Office hours facilitate better discussion for problem-solving steps.	High-performing: Hearing about crowded office hours deters students from attending. Average-performing: Same as high-performing Low-performing: (a) Office hours provide and facilitate students' mentorship, and (b) in large courses students need persistence to attend office hours.
In-class demonstrations / simulations / models / animations	Low-performing: Demonstrations in lectures become the spectacle.	High-performing: Lectures using models help students to visualize content.

Table 4-15. Continued

BL affordance	PHY 2048	CHM 2046
	Nontraditional learning methods	
Online homework	High-performing: (a) Online homework gauges students' understanding, and (b) online homework pushes students to find help to understand information. Average-performing: (a) Online homework provided easy practice, (b) online homework frustrates AL due to its reliance on the succession of correct answers, and (c) same as (b) with high-performing.	High-performing: (a) Online homework provides conflicting feedback about students' understanding, and (b) online homework questions reinforce content in lectures but not in exams. Average-performing: (a) Online homework can be confusing because inputting information is also assessed, and (b) online homework does not support conceptual understanding. Low-performing: (a) Online homework stonewalls students' problem solving if students cannot solve all subquestions, and (b) same as (a) with average-performing.
Online videos / pre-class videos	High-performing: Online videos created by the instructor are treated as optional resources. Average-performing: Access to online videos not memorable.	High-performing: Pre-class videos can be redundant to information presented at the beginning of lectures. Average-performing: Pre-class videos are good brain-priming stimuli. Low-performing: Same as average-performing

Table 4-15. Continued

BL affordance	PHY 2048	CHM 2046
	Nontraditional learning methods continued	
In-class clicker questions	High-performing: In-class clicker questions test basic knowledge, and (b) in-class clicker questions instigate small group discussion. Average-performing: (a) in-class clicker questions motivate students to attend lectures, (b) in-class clicker questions encourage students to teach each other, and (c) in-class clicker questions does not instigate stress. Low-performing: Same as (a) and (b) with average-performing.	High-performing: In-class clicker questions enable collaborative problem solving. Average-performing: Same as high-performing
LMS	Low-performing: Discussion in LMS facilitates small groups.	High-performing: The LMS fosters students' review of information shared during lectures and before the discussion classes. Average-performing: Same as high-performing

Table 4-15. Continued

BL affordance	PHY 2048	CHM 2046
	Additional resources	
Resources	High-performing: (a) Friendly mentors can benefit students, (b) online resources show how to solve problems when students are ready to solve problems, and (c) Study Edge© is a necessary resource to use before taking the exam. Average-performing: (a) Additional online resources dispel confusion for problem solving, (b) Study Edge© is a student-trusted course that students believe will help them do better on the PHY 2048 exams, and (c) Study Edge© can give students false confidence. Low-performing: Instructor-provided BL affordances are not worth students' time compared to Study Edge© BL affordances, (b) quiz grades improved by Study Edge©, (c) Study Edge© targets information to be tested on the exam, (d) tutoring support gives students false confidence, and (e) same as (c) with high-performing.	High-performing: (a) Study Edge© provides a final check of student understanding before the exams, and (b) the search for online resources develops students' metacognitive awareness. Average-performing: (a) Study Edge© shares testable knowledge with students in most condensed way, and (b) same as (b) with high-performing. Low-performing: (a) Study Edge© confused students with conflicting priorities on what to study, (b) Study Edge© gave students a false confidence in its ability to help them do well on the exam, and (c) outside of class students required mentorship.

Researcher's review of documentations of blended learning affordances for active learning

Students in PHY 2048 located documentations in two main areas: the course website and the course LMS. Students in CHM 2046 located documentations primarily on the course LMS, and the syllabus reported the most information. The CHM 2046 documentations shared directions about assignments, course expectations with students, and information about resources like the tutoring center. Few connections were made between the instructor's expectations and the instructor's intent for AL that was mentioned in her interview. Nevertheless, the instructions for the assignments predominantly encouraged reading, reflecting, and/or problem solving. For example, in the syllabus, the directions with the in-class clicker questions and the worksheets to be submitted in the discussion class included:

> Five percent of the course grade (50 points) will be based on performance on in-class clicker questions and in-discussion worksheets. You can earn points in class by correctly answering clicker questions through Learning Catalytics© (1/2 point per correct answer). You can also earn points by completing worksheets in the discussion sections (1 point per worksheet).

In the course overview section for PHY 2048, although the terms "blended learning" and "active learning" were not used, the instructor did explain how the BL affordances related to AL. For example, the following was the expectations for the lectures and discussion classes:

> We cannot stress enough the importance of coming to class. Frequent class skipping contributes strongly to poor student performance. However, attending classes and doing something else at the same time like reading papers, browsing internet, texting/emailing, doing homework, etc. is a waste of your time. ***Read ahead before lecture***: even though you may not understand the chapter material, advance reading "primes" your brain to be receptive to the material when it is discussed in lecture or discussion. ***Be proactive and ask questions***: as you learn new concepts, your questions cannot possibly be wrong or stupid and are very likely to be widely shared.

As seen in Figure 4-3 and in Figure 4-8, the documentations for both courses identified BL affordances beyond the ones identified by the interviewed students. Within the LMS for CHM 2046, the instructor made announcements in the LMS, encouraged students to monitor their grades in the LMS gradebook, and requested student feedback via the online course evaluations. The announcements maintained communication between instructor and students, the gradebook informed students what activities needed attention, and the evaluations provided students the opportunity to note what affordances enabled or constrained AL. The syllabus identified many of the affordances that the students discussed. It also encouraged the students to attend the Chemistry Learning Center for extra tutoring as needed; however, the many of the students chose to go to Study Edge© instead.

Many of the PHY 2048 BL affordances identified in the students' interviews were also found in the Course Overview, the course's online version of a syllabus. Information about a tutoring center was also shared with students, but many of the interviewed students decided to go to Study Edge© instead. Additionally, the documentation encouraged students to discuss questions via the Chat feature in the LMS. In the LMS, the BL affordances matched the ones discussed by the interviewed students except there is the encouragement for students to email instructors with questions—a practice not encouraged by the CHM 2046 instructor.

Researcher's observations of blended learning affordances for active learning

The layout and equipment in the classrooms for both courses were similar to each other, except students in PHY 2048 had long tables to write upon rather than the smaller side tables that slid up from the seats in the auditorium housing the CHM 2046 lectures. Both courses structured their courses to have FTF lectures, online homework, online videos, FTF discussion classes, and exams. However, the CHM 2046 instructor more purposefully selected or created pre-class videos that were no longer than 10 minutes, conversed with students during lecture and would not move forward with lecturing until a student responded, and the discussion classes were more like workshops in which students needed to submit worksheets that could be completed alone or together and had to be checked by teaching assistants for correctness. Teaching assistants were more visible and accessible in CHM 2046, as they were required to walk up and down aisles during in-class clicker questions and work together in a group of three (one graduate student and two undergraduate students) to help students during discussion class. Teaching assistants also held office hours and led their own exam reviews. In PHY 2048, the instructor structured lecture to focus more on problem solving rather than introducing concepts in detail; according to the interview with the instructor, the online videos were available to students to watch the breakdown of a concept at their leisure. Quizzes after discussion were designed to emulate conditions for the exam. The teaching assistant lectured in discussion and held office hours.

The results from the use of PORTAAL in both courses are presented in Table 4-16.

Table 4-16. Comparison of both courses' PORTAAL percentages (% of observed course activities)

PORTAAL element	PHY 2048	CHM 2046
Dimension 1: Practice		
P1. Frequent practice	76%	87%
P2. Alignment of practice with assessment	33%	80%
P3. Distributed practice	77%	67%
P4. Immediate feedback	33%	93%
Dimension 2: Logic Development		
L1. Frequent opportunities to practice higher order skills in class	33%	80%
L2. Prompt student to explain / defend their answers	93%	67%
L3. Allow student time to think before they discuss answers	17%	73%
L4. Students explain their answers to peers	17%	73%
L5. Students solve problems without hints	85%	27%
L6. Students explain logic behind their answers in front of whole class so instructor can hear and respond to their ideas	33%	60%
L7. Logic behind correct answer explained	33%	53%
L8. Logic behind why incorrect answers incorrect explained	0%	7%

Table 4-16. Continued

PORTAAL element	PHY 2048	CHM 2046
Dimension 3: Accountability		
A1. Activities worth course points	33%	73%
A2. Activities involve small group work so more students have opportunity to participate	17%	53%
A3. Avoid volunteer bias by using cold or random call	0%	0%
Dimension 4: Apprehension reduction		
R1. Give students practice participating by enforcing participation through random call	0%	0%
R2. Student confirmation: Provide praise to whole class for their work	30%	13%
R3. Student confirmation: Provide praise to individual students	23%	53%
R4. Student confirmation: Do not belittle student responses	100%	100%
R5. Error framing: Emphasize errors are natural or instructional	25%	33%
R6. Emphasize hard work over ability	62%s	60%

Key points related to the dimension of practice included students in CHM 2046 had the opportunity to talk 87% of the time, while in PHY 2048 they had 76% of the time. The PHY 2048 encouraged the students to use prior knowledge for 77% of the activities, while the CHM 2046 instructor encouraged students to exercise prior knowledge for 67% of the activities. Both exams for the courses required higher order skills for the entire exam, yet the physics students only exercised higher order skills during 32% of class activities and chemistry students 80% of the class activities.

On the dimension of logic development, major differences were that 93% of the observed physics activities reminded the students to use logic, but only 17% of the physics activities allowed students time to think alone or to discuss their logic. In CHM 2046 students were reminded to use logic in 67% of the activities, but they did have 73% of activities to think a problem through by themselves or to talk to other students. The instructor in PHY 2048 did not explain why incorrect answers were incorrect, while the instructor in CHM 2046 only did so 7% of activities.

Highlights from both courses on the dimension of accountability showed that 73% of the observed chemistry activities were worth points, while 33% of the observed physics activities were not worth points. Both instructors did not call on students randomly.

In regard to the fourth dimension of apprehension reduction, the physics instructor praised the class during 30% of the activities and an individual student during 23% of the activities. The chemistry instructor praised the class during 15% of the activities, but praised individual students during 53% of the activities. At no time did the instructors make negative comments to the students.

Addressing Proposition 2: Relationship between Blended Learning Affordances and Active Learning Encourages or Discourages Student Persistence

The second research question examined how the influence of BL affordances influenced student persistence in the form of the students’ motivation, confidence, science learning, and identification as a scientist (see Figure 2-8 for conceptual framework). In the interviews the students shared how BL-AL affordances influenced the four areas of persistence as presented by Graham and his associates (2013). The results from the survey provide more details about the surveyed population and how their responses to the BL4AL survey instrument predict their persistence in the sciences.

Students’ perspective related to their motivation, confidence, science learning, and identification as a scientist

Emerging themes within the four areas of motivation, confidence, science learning, and identification as a scientist showcased the students’ perspectives on persistence in the course and in the sciences (see Table 4-17). Responses highlight which BL-AL affordances influenced the four areas; however, some responses are subjective statements that may not directly relate to BL affordances or AL. These comments were retained to provide more context to the responses. Similar to the comparison of students’ perspective on BL affordances for AL, Table 4-17 exhibits the representative themes from the high-performing, average-performing, and low-performing interviewed groups.

Responses from BL4AL as indications of students’ motivation, confidence, science learning, and identification as a scientist

A higher percentage of students in CHM 2046 (43.1%) responded to BL4AL in comparison to students in PHY 2048 who responded (30.2%). Because CHM 2046 was the second course in the two-course General Chemistry series, 43.4% of the students had already taken three to four other science courses, while 23.7% of physics students had taken three to four other science courses. Among the PHY 2048 respondents, 81.1% were freshmen, while 69.9% of CHM 2046 respondents were freshmen. All respondents to BL4AL in PHY 2048 expected to earn at least a C in the course, and

3.5% expected to earn a C. In CHM 2046, 8% of the respondents predicted they would earn a C, and 1% below a C. The descriptive statistics for both cases are similar.

Table 4-17. Mean of aggregate scores and average standard deviation for each of the four persistence dimensions for traditional or nontraditional learning methods in both courses

	PHY 2048		CHM 2046	
Variable	*M*	*SD*	*M*	*SD*
Motivation-traditional learning methods	2.47	1.02	2.36	1.04
Motivation-nontraditional learning methods	2.57	1.07	2.55	1.06
Confidence-traditional learning methods	2.45	1.03	2.33	0.97
Confidence-nontraditional learning methods	2.55	1.08	2.51	1.02
Science learning-traditional learning methods	2.35	0.96	2.30	0.96
Science learning-nontraditional learning methods	2.50	1.03	2.45	1.00
Identification as a scientist-traditional learning methods	2.58	1.05	2.56	1.07
Identification as a scientist-nontraditional learning methods	2.68	1.09	2.65	1.07

Whether the students perceived that course influenced them to continue in the sciences, 57.4% of students in PHY 2048 strongly agreed or agreed the course did influence, while 68.9% of students in CHM 2046 strongly agreed or agreed; 27.6% in PHY 2048 and 20.9% of students in CHM 2046 were neutral; and 14.5% in PHY 2048 and 10.2% in CHM 2046 disagreed or strongly disagreed. Using the results of the BL4AL as predictors to the students' motivation to continue in the sciences, a significant regression equation with a medium effect size was found for both courses— $F(8, 218) = 7.69$, $p < .01$, $f^2 = .28$ for PHY 2048 and $F(8, 293) = 6.84$, $p < .01$, $f^2 = .19$ for CHM 2046. Two regression equations were conducted due to the overall research design to consider the cases separately from each other. Two BL4AL predictors, motivation—

traditional learning methods and confidence—traditional learning methods, were significant to predict whether PHY 2048 students were influenced by their perceptions of their respective course to continue in the sciences. Only one predictor, confidence—traditional learning methods, was significant to predict whether CHM 2046 students perceived that they were continuing in the sciences due to the course. The BL4AL results in PHY 2048 explained 19% of the variance in the model, while the results in CHM 2046 explained 13%.

A model including a grouping variable was tested through sequential regression. The interaction between the centered average scores of the factors within BL4AL and the grouping variable showed only a small change in R^2 (ΔR^2 = .01, $F(1, 518) = 5.87$, $p < .02$, $f^2 < .01$).

Table 4-18. Model summary of results when grouping considered

Model	R	R^2	Adjusted R^2	Std. error of the estimate
1	.20	.04	.02	1.00
2	.22	.05	.03	1.00

CHAPTER 5
DISCUSSION

The study investigates how BL affordances can enable or constrain AL components. An affordance represents "the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used" (Norman, 1988, p. 9). Each BL affordance was evaluated along four dimensions: space, time, fidelity, and humanness (Graham, 2006). The components constituting AL represent the features of AL in the courses; the features being divided into three categories: basic elements, teaching resources, and learning strategies (Meyers & Jones, 1993). The conceptual framework that BL affordances enable or constrain AL practices also included that the BL-AL relationship influences student persistence. Two research questions were addressed in this study:

- How do BL affordances for AL practices manifest in introductory science courses?
- According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses?

This chapter discusses the findings relative to each question, implications for research, design, and education, the limitations to the study, and a conclusion to the study.

Blended Learning Affordances for Active Learning

According to Graham (2006), the definition of BL goes beyond a blending of online and FTF activities. Rather, the blending occurs along four dimensions: space (online to FTF), time (synchronous to asynchronous), fidelity (rich to all senses to text only), and humanness (high human / no technology to no human / high technology). Furthermore, BL occurs at multiple levels such as at the course and activity levels (Drysdale et al., 2013; Graham, 2006). The activities within the course constitute the course blending (Graham, 2006). The BL affordances were not considered merely as components or functions within a blended course, but they were specific activities within the course that fell along Graham's (2006) four dimensions for BL and that elicited experiences that could enable or constrain AL. When examining PHY 2048 and CHM 2046, the researcher evaluated BL at the course level, looking for the BL affordances within each course. Thus, although online homework itself has no FTF component, it constitutes a part of a BL course. When examined as a BL affordance, the students experience online homework as being online, asynchronous, text only, and no human interaction and high technology interaction; however, that online homework also becomes the basis for the discussions class and preparation for the FTF lectures and for the exams.

Within the two cases, BL affordances were identified by the instructors and students, and the BL dimensions for the affordances differed from one another. For example, in CHM 2046 the FTF lectures were synchronous, students could see and listen in class, and had opportunities to interact with the instructor or other students. In the same course the FTF lectures blended with online homework, which was asynchronous, forced students to problem solve more than watching and listening, and encouraged personal work rather than group work. The PHY 2048 FTF lectures were also synchronous, students watched and listened to lecture, but there were fewer opportunities for student-instructor or student-student interaction. Based on the observations, 17% of the PHY 2048 activities allowed for small group work in comparison to the 53% of activities allowed in CHM 2046. Thus, with the varying dimensions of BL, the AL was either constrained or enabled.

Through the triangulation of the findings from the interviews, documentations, and surveys, the cross-case analysis of the two cases supported the argument that BL affordances enable or constrain learning (cf., Kozma, 1991, 1994; Graham, 2013). However, the findings indicate a discrepancy between how instructors and how students consider which BL affordances enable or constrain AL. In the research design student volunteers for the interviews were chosen so that there would be two high-performing, two average-performing, and two low-performing students. As seen in Table 4-4 and Table 4-11 there were no patterns to how each of the students in each group responded to which BL affordances enabled or constrained their AL in the courses. Requiring more investigation in future studies, rather than student performance, students' feelings of self-efficacy, personal learning preferences, or past experiences with BL in science courses may be other factors that more consistently influence students' perspectives of BL affordances. Based on the results of the presented study, regarding the online homework in CHM 2046, one interviewed student in the high-performing group and one interviewed student in the low-performing group indicated the homework constrained AL. Both average-performing students agreed with the instructor that the online homework was helpful. An example in PHY 2048 was that one low-performing student, both average-performing students, and one high-performing student indicated that the FTF exam was a constraint to AL. By suggesting that certain BL affordances enabled and constrained AL, the students were suggesting that their experiences with BL influenced their learning having characteristics such as engaging the students in the learning process with activities that are constructivist in nature (Freeman et al., 2014; Kober, 2014; Loyens, 2007; Prince, 2004). The resulting emerging themes from the cross-case analysis detail the influences of instructor-identified traditional learning methods (e.g., FTF lectures, office hours, and exams), instructor-identified nontraditional learning methods (e.g., in-class clicker questions, online videos, and the LMS), and additional resources not facilitated by the instructor but chosen by the students to become part of their BL experience. The first research question asked: How do BL affordances for AL practices manifest in introductory science courses? The following details the takeaways from the study in response to the question—the identification of BL affordances influencing the students' AL (see Table 5-1).

Face-to-Face Lectures

Because the sciences, particularly the introductory sciences, have focused so much on FTF lectures, the affordance of FTF lectures had one of the most identified themes (as seen in Table 4-13; Baepler et al., 2014). However, the themes present different perspectives of the affordance in each course. As supported by the interviews and observations, in PHY 2048 students considered the FTF lectures a required spectacle, in which students watched and listened to the instructor present physics concepts but could avoid class participation. Depending on where students sat in the classroom, information whether written on the board or presented in a Microsoft® PowerPoint was inaccessible to students because they were unable to read the information. The most concerning theme that emerged was that the FTF lecture did not adequately prepare students to visualize the physics concepts, which as the instructor indicated should be one of the major practices for students when completing the online homework. According to Graham's (2006) four dimensions of BL, the lectures were FTF, synchronous in time, somewhat rich to all senses, but low human interaction was apparent. Although the FTF lecture was also required in CHM 2046, the style of the lecture was more of an interactive “conversation” between the instructor and students. When talking about the FTF lecture, the students not only focused on the lecture but also indicated how the models used in class, online homework, pre-class video, in-class clicker questions, and the LMS related to the lecture. The students were able to identify the role of the affordances as a chronological learning strategy created by the instructor, for example, one needed to complete the pre-class video to be prepared for the initial in-class clicker question and following lecture—following the prescribed learning experience as noted in the course documentations. Although the students mainly watched or listened to the instructor, her interactions with the students more actively engaged their critical thinking and helped them to verbalize their thoughts. In the interview with the students all of them spoke highly of the instructor, which lends to the possibility that the person of the instructor constitutes a good lecture. Despite the positive experiences with the instructor in lecture, an emerging theme was that the lecture itself was unable to help students solve problems on their own. Students requested more ways to participate in class and more specific directions as to what and how much information from the lectures to retain. Nevertheless, overall, the BL affordance was FTF, synchronous in time, somewhat rich to all senses, but had high human interaction (Graham, 2006).

Based on the students’ experiences, students in PHY 2048 indicated the FTF lectures partially enabled AL components identified within Meyers and Jones’s (1993) AL framework like writing and reflecting, but they partially constrained AL components like conceptualizing content and problem solving. Students in CHM 2046 indicated the FTF lectures enabled AL components like answering questions and discussions.

In-Class Demonstrations, Models, and In-Class Clicker Questions

During the study, in-class demonstrations, models, and in-class clicker questions were not considered as part of the FTF lectures because the instructor and students had identified them as separate BL affordances. However, in the operation of a FTF lecture the three affordances often supplement the instructor's lecture. In both courses demonstrations and models were portrayed as a help for students to visualize concepts; however, the demonstrations in PHY 2048 may become another spectacle for students in addition to the lectures when they may not understand the content being discussed in class. According to Graham's (2006) BL framework, in-class demonstrations were FTF, synchronous, closer on the spectrum to being rich to all senses, and in the middle of the spectrum between only human interactions and only technology interactions.

Although there were mixed responses to the enablement or constraint caused by FTF lectures, the in-class clicker questions were designated more consistently as an enablement to AL (see Table 4-4 and Table 4-11). As seen during the in-class observations, instead of merely testing students' understanding of basic information or encouraging students to attend class, the BL affordance became the catalyst for student engagement with one another. Students discussed the different problems and answers choices. Students unsure about how to solve a problem received help from more knowledgeable students. In self-made small groups students discussed why answers were correct or why they were incorrect. Thus, it facilitated a discussion of alternative answers in comparison to the correct one—a practice absent from the observed PHY 2048 activities and present in only 7% of CHM 2046 activities. The BL affordance was FTF, synchronous, middle of the spectrum between only text and rich to all senses, and not only high human interactions but also high technology interactions (Graham, 2006).

The students' experiences in both courses indicated that in-class demonstrations and models enabled AL components such as watching and reflecting for the interpretation and re-creation of models (Campbell, Planinz, & Miller, 2016). In-class clicker questions constituted a BL affordance that enabled AL components such as talking, listening, and reflecting for problem solving.

Online Videos and Online Homework

Preparing students for lecture both courses used online videos, and students' experiences varied for both online videos and online homework. Both instructors indicated they wanted students to be prepared for lecture, and the CHM 2046 instructor expressed the post-class homework was meant to solidify understanding of materials. However, in PHY 2048 a theme for online videos was the students' consideration of the videos being not memorable or being optional to watch, although they were required to be watched before class according to the Course Overview. Similarly in CHM 2046, a theme of being optional also developed related to the videos, but the students did identify them as ways to "prime" the brain.

The online homework resulted in mixed reactions to its being an enablement or constraint to AL. Although problem solving was involved in the process, students would not know how accurate their problem-solving skills were. The online homework questions for both courses consisted of multiple sub-questions to one question, and not answering one correctly would cause the final answer to be incorrect—students then being unable to target which areas of weakness they had. Although some problems did help students to practice concepts presented in class or on the exam, at times there was a disconnect between materials and skills being assessed in the online homework and for an exam. During the online homework process, students would be assessed by how they input numbers or other types of answers in the online system rather than on whether they correctly problem solved—the main purpose of the exam. The experiences would frustrate the students and, thus, their AL. Following Graham's (2006) four dimensions, the online videos and the online homework were online, asynchronous, middle of the spectrum between only text and rich to all senses, and low human interactions and high technology interactions.

The PHY 2048 students in general regarded online videos as a partial enablement and as a partial constraint. Students recognized the videos prepared students for lecture, but primarily due to the length, students passively watched the videos, if they watched the videos at all. The CHM 2046 students in general indicated the online videos enabled AL, preparing them for lectures and encouraged them to exercise reflection skills (Mok, 2014). Regarding the online homework, students from both courses regarded the affordance as a partial enablement and a partial constraint. Students reflected on content for problem solving, but their problem solving skills were impeded by needing to learn other types of skills such as inputting answers for online grading.

Exams

The ultimate similarity for both courses were the exams that caused student apprehension. Despite the BL affordances to assist the students to prepare for the exams, students did address the exams as motivators to study course materials and to practice key physics or chemistry concepts on the practice exams. However, the pressure to do well or to merely pass the exams increased anxiety. Although every BL affordance was discussed in its relation to how it helped or did not help the students on the exams, students continued to describe exams as mysterious—students indicating they thought they did well on the exams but were unsure why they did not, even with access to the answer keys after the exam. The BL affordance was FTF, synchronous, text only, high human interactions and low technology interactions (Graham, 2006).

Students in both courses also indicated that exams were a partial enablement and a partial constraint to AL. Students engaged in reflecting on concepts and problem solving; nevertheless, it was unclear to students to what end was the problem solving—taking the exams to earn good grades or understanding content to apply information beyond multiple-choice answers (Savery, 2015).

Instructor-Identified and -Supported Additional Blended Learning Affordances

As part of the course design, as seen in the documentations, the instructors also offered BL affordances like office hours (including email and online chat options for PHY 2048 and the review of online homework questions in CHM 2046) and the course LMS. Although the purpose of office hours was to provide students access to the instructor for extra help outside of lecture, students in PHY 2048 found the one office hour availability a week for the instructor to be inconvenient in time and in location, and they did not choose to utilize the online options. The CHM 2046 had office hours Monday through Friday, yet the popularity of the office hours deterred students from going—they wanted the one-on-one attention and did not want to meet in groups or to wait for individual attention. Although under-utilized, the LMS in both courses did allow for individual voices to be heard. For example, students used the discussion feature in the LMS to communicate their questions about exam problems or frustrations with the online homework system with each other. As a BL affordance, the LMS was online, asynchronous, only text, high human interactions and low technology interactions.

Students in both courses indicated that office hours partially enabled and partially constrained AL. They provided opportunities discussion and problem solving with the instructors, but the implementation of office hours discouraged some students from participation; for students in both courses, the LMS enabled AL, encouraging students to pose and to respond to questions for problem solving (Freeman et al., 2014).

Student-Identified Additional Blended Learning Affordances

Outside of the instructor-identified and -supported BL affordances were ones students used to improve their experience with the instructor-identified affordances. Three major affordances included (1) outside-of-class meetings between students and friends who acted as mentors and tutored them in problem solving, (2) online resources like YouTube© and Chegg© to guide students through the problem-solving process, and (3) Study Edge©, which essentially for students became a non-graded copy of their courses. These affordances were considered a part of the course due to their contributions to the students' overall experience with the course. In their recollection of either PHY 2048 or CHM 2046, students identified the affordances, which ultimately influenced their learning experiences in their respective course. For example, when Chloe, an average-performing student in PHY 2048, recollected her experiences with the exams, she described her experiences with Study Edge© as a component to her preparation for the exam.

For the first identified affordance, meeting with a more knowledgeable friend or mentor demanded more initiative from the students. They needed to be more cognizant of areas of weakness and take the time to work with someone else. Following Graham's (2006) four dimensions for BL, the mentorship times were FTF, synchronous, middle of the spectrum between text only and rich to all senses. The second affordance with the use of online resources also demanded student initiative, requiring students to spend time with the resources and to identify what was helpful or unhelpful resources. As a BL affordance, the online resources were online, asynchronous, closer to being rich to all senses, and low human interactions but high technology interactions (Graham, 2006). The third affordance required students to pay $25, $50, or $75 for a subscription with the tutoring service Study Edge©, and students took initiative to determine what BL affordances from Study Edge© would be useful to them (e.g., FTF or online recordings of chapter reviews and exam reviews). Study Edge© essentially provided students with the same BL affordances as their courses FTF lectures, online videos to reinforce concepts or to prepare for lectures, practice exams, and individual tutoring similar to office hours. Nevertheless, students paid to use the Study Edge© affordances rather than the ones provided by the instructor. For example, students devoted time to Study Edge© sessions and watched videos shared by Study Edge© via Facebook© but never attended office hours nor watched an instructor-produced video.

As a BL affordance, Study Edge© also had sub-affordances that had varying spaces, time, fidelity, and humanness (Graham, 2006). Although Study Edge© created similar BL affordances for students as the instructors in PHY 2048 and CHM 2046 did, the overall Study Edge© experience was considered as one affordance in the study due to the service allowing students to be able to select which affordances they wanted to utilize—contrary to the must-do attitude in the respective courses. Additionally, because students paid for the tutoring services and chose which affordance they thought would complement or supplement their learning, the students’ initiative qualified Study Edge© to be a BL affordance for AL (cf. Grabinger & Dunlap, 1995; Niemi, 2002; Wilson, 2013).

For students in both courses, the affordances of mentorship times, online resources, and Study Edge© enabled AL components such as discussions, reflection, and problem solving. Based on Yin's (2014) recommendation, the conceptual framework (Figure 2-8) was modified after the cross-case analysis and discussion. In Table 5-1 the results from the two case studies provided more details about the BL affordances and their relationship to AL. The BL affordances were characterized according to the dimensions of space, time, fidelity, and humanness (Graham, 2006), and the activities were designated according to Meyers and Jones's (1993) AL framework.

Table 5-1. Relationship of BL affordances on AL based on case studies

PHY 2048 / CHM 2046	BL affordance	BL dimensions				AL components			Constraint / enablement / both
		Space	*Time*	*Fidelity*	*Humanness*	*Basic elements*	*Teaching resources*	*Learning strategies*	
	FTF lectures								
PHY 2048		FTF	Synchronous	Middle of text only and rich to all sense	Mid human / mid technology	Writing and reflecting	Prepared content and questions	Problem solving	Both
CHM 2046		FTF	Synchronous	Middle of text only and rich to all sense	High human / mid technology	Talking and listening	Prepared content and questions	Discussions	Enablement
	In-class demonstrations and models								
PHY 2048		FTF	Synchronous	Closer to rich to all senses	Mid human / mid technology	Watching and reflecting	Prepared materials, technology, and models	Simulations	Enablement
CHM 2046		FTF	Synchronous	Closer to rich to all senses	Mid human / mid technology	Watching and reflecting	Prepared materials, technology, and models	Simulations	Enablement
	In-class clicker questions								
PHY 2048		FTF	Synchronous	Middle of text only and rich to all sense	High human / high technology	Talking, listening, reflecting	Questions, educational technology	Discussions, problem solving	Enablement
CHM 2046		FTF	Synchronous	Middle of text only and rich to all sense	High human / high technology	Talking, listening, reflecting	Questions education technology	Discussions, problem solving	Enablement

Table 5-1. Continued

PHY 2048 / CHM 2046	BL affordance	BL dimensions				AL components			Constraint / enablement / both
		Space	*Time*	*Fidelity*	*Humanness*	*Basic elements*	*Teaching resources*	*Learning strategies*	
	Online class videos								
PHY 2048		Online	Asynchronous	Middle of text only and rich to all sense	Low human / high technology	Watching, reflecting	Prepared materials, multimedia	Problem solving	Both
CHM 2046		Online	Asynchronous	Middle of text only and rich to all sense	Low human / high technology	Watching, reflecting	Prepared materials, multimedia	Problem solving	Enablement
	Online homework								
PHY 2048		Online	Asynchronous	Text only	Low human / high technology	Reflecting	Problems	Problem solving	Both
CHM 2046		Online	Asynchronous	Text only	Low human / high technology	Reflecting	Problems	Problem solving	Both
	Discussions								
PHY 2048		FTF	Synchronous	Middle of text only and rich to all sense	Mid human / low tech	Talking, listening, reflecting	Online homework	Problem solving	Constraint
CHM 2046		FTF	Synchronous	Middle of text only and rich to all sense	High human / low tech	Talking, listening, reflecting	Prepared worksheet	Problem solving	Enablement
	Exams								
PHY 2048		FTF	Synchronous	Text only	Low human / low tech	Reflecting	Problems	Problem solving	Both
CHM 2046		FTF	Synchronous	Text only	Low human / low tech	Reflecting	Problems	Problem solving	Both

Table 5-1. Continued

PHY 2048 / CHM 2046	BL affordance	BL dimensions				AL components			Constraint / enablement / both
		Space	*Time*	*Fidelity*	*Humanness*	*Basic elements*	*Teaching resources*	*Learning strategies*	
	Office hours								
PHY 2048		FTF, online	Synchronous	Text only	High human / low tech	Reflecting	Prepared questions	Problem solving	Both
CHM 2046		FTF	Synchronous	Text only	High human / low tech	Reflecting	Prepared questions	Problem solving	Both
	LMS								
PHY 2048		Online	Asynchronous	Text only	High human / high tech	Writing, reading, reflecting	Student questions	Discussions	Enablement
CHM 2046		Online	Asynchronous	Text only	High human / high tech	Writing, reading, reflecting	Student questions	Discussions	Enablement
	Mentoring (student identified)								
PHY 2048		FTF	Synchronous	Middle of text only and rich to all sense	High human / mid tech	Talking, listening, reflecting	Prepared questions	Problem solving	Enablement
CHM 2046		FTF	Synchronous	Middle of text only and rich to all sense	High human / mid tech	Talking, listening, reflecting	Prepared questions	Problem solving	Enablement
	Online resources (student identified)								
PHY 2048		Online	Asynchronous	Closer to rich to all senses	Low human / high tech	Reading, reflecting	Prepared materials, multimedia	Problem solving	Enablement
CHM 2046		Online	Asynchronous	Closer to rich to all senses	Low human / high tech	Reading, reflecting	Prepared materials, multimedia	Problem solving	Enablement

Table 5-1. Continued

PHY 2048 / CHM 2046	BL affordance	BL dimensions				AL components			Constraint / enablement / both
		Space	*Time*	*Fidelity*	*Humanness*	*Basic elements*	*Teaching resources*	*Learning strategies*	
	Study Edge©								
PHY 2048		Varying on spectrum of space	Varying on spectrum of time	Varying on spectrum of fidelity	Varying on spectrum of humanness	Listening, writing, reading, and reflecting	Outside speakers, online applications, prepared educational materials	Discussions, problem solving	Enablement
CHM 2046		Varying on spectrum of space	Varying on spectrum of time	Varying on spectrum of fidelity	Varying on spectrum of humanness	Listening, writing, reading, and reflecting	Outside speakers, online applications, prepared educational materials	Discussions, problem solving	Enablement

The Influence of the Relationship between Blended Learning Affordances and Active Learning on Student Persistence

The findings from the student interviews and the survey helped explore the influence of BL affordances and AL on student persistence in a couple of ways. The responses to the interviews showcased that the students' thoughts of persistence—in this case, Graham and associates' (2013) four components of motivation, confidence, science learning, and identification as a scientist—may not directly relate to BL or AL. For example, the students in both courses were often motivated to persist by their grades on assignments in the overall course and, more so, by their career path goals (e.g., to be an engineer or a physician's assistant). Similar to Frank and associates' (2003) qualitative study about the perceptions and attitudes of freshmen in an introductory project-based learning course in engineering, students in PHY 2048 and CHM 2046 were motivated to stay in the course, learn the concepts necessary for their chose career paths, and move on to the next required course. Nevertheless, as seen in Table 4-14, BL affordances and AL practices were also discussed as influencing student persistence. The BL4AL model explained 19% of the variance in overall persistence in PHY 2048 and 13% of the variance in CHM 2046.

The second research question stated: According to the perceptions of students, how do BL affordances for AL practices influence student persistence and course performance in introductory science courses? The takeaways in response to the question include BL affordances particularly influencing student motivation and student confidence and potential modifications to the BL4AL instrument.

Student Motivation

In the interviews for both courses, in addition to the emerging themes of external factors requiring students to continue on academic science tracks (e.g., good grades, career goals, and department requirements) and subjective factors (e.g., desire to learn and interest about the subject), the students discussed how BL affordances influenced AL practices. In PHY 2048 in-class clicker questions helped students to focus on important content information, and the ability to know important information and to earn “easy points” for doing so was a motivation to remain in the course. As an additional BL affordance, the use of Study Edge© was a motivating factor, in that a financial cost was paid—an investment to do well in the course. In CHM 2046, students emphasized the important of the instructor’s role within the BL affordance of FTF lectures. Students credited the instructor’s passion for teaching and her presentation of the content as reasons to remain motivated in the course.

In response to the BL4AL survey, although the results from the items related to student motivation and the different types of learning methods were insignificant in CHM 2046, the results of motivation through traditional learning methods were found to be significant—at least indicating that the motivation encouraged by traditional learning methods (i.e., FTF methods) in the course increased the students’ desire to persist in the sciences. As possible explanations of the results, due to traditional learning methods like lectures being emphasized and exams being worth the most points in the course, students indicated the traditional learning methods influenced their motivation more than nontraditional learning methods. The results also confirmed Graham and associates’ (2013) argument that “it is imperative that persistence efforts address motivation and confidence” (p. 1455).

Student Confidence

While motivation encouraged the students to continue in the course, confidence predominately provided students with the assurance they either understood the course materials or were able to do well the assessments. Although good grades on exams reinforced confidence, and helped determine confidence in general, other BL affordances initiated confidence for students. Study Edge© bolstered confidence—students identified their need for help, initiated a subscription with Study Edge©, selected resources provided by the service, practiced to review feedback about strengths and weaknesses, and moved forward to in-class activities with more confidence. Despite the confidence booster, Study Edge© did create false confidence for some of the students. Rather than empower the students, it crippled some to depend on its resources so that, during an exam, they were unable to solve the problems on their own because they had not practiced on their own. Although the numbers are too small to generalize, the two students who did not use Study Edge© were high-performing students who endeavored to solve problems by themselves in practice for the exams. The theme of depending on BL affordances too much coincided with the theme that the selection of BL affordances determined which students were more confident. The confident students articulated their strengths and weaknesses and how the BL affordance either nurtured or hindered the strengths and weaknesses, respectively. Less confident students relied on as many BL affordances as possible without discretion as to which one assisted personal learning. The BL4AL results for student confidence and traditional learning methods were significant in both courses—the only significant factor in CHM 2046. The significant results indicate that the students' responses to how they viewed the influence of traditional learning methods (e.g., FTF lectures and exams) and confidence predicted whether students would continue in the sciences due to the course, supporting Graham and associate's (2013) argument that confidence is a key factor for student persistence. The BL4AL results also indicated that among the two cases, students' perceptions of nontraditional learning methods and confidence were not significant indicators to their persistence in the sciences. Possible reasons may be that being physically able to do something encourages confidence, and parameters are still being developed for nontraditional learning methods, thereby leading to students being unsure of their work. For example, with the online homework, students had points deducted because they did not input their answers correctly; thus, students may have understood the materials but were unsure because they did not earn maximum credit.

Science Learning

Although the entire study about the influence of BL affordances on AL for student persistence was embedded in undergraduate science learning, the themes related to science learning as a factor in student persistence highlights how students perceive the effect of BL affordance on their science learning as a determinant of student persistence (Graham et al., 2013). In general, BL affordances benefited when they were tied to real-world context and applications, developing the students' mindset to solve authentic problems. Online applications like Chegg© modeled the problem-solving process to students; however, the challenge for students was to have adequate BL affordances that could assist the students with fully visualizing concepts and problems being posed to students. Related to student confidence, science learning with BL affordances was hindered when students did not know how to appropriate the affordances, or, in some cases, students benefited from a BL affordance but did not utilize the affordance to its full potential. For example, the instructor-created or instructor-shared videos were shared with students to prepare them for class, but few mentioned how the videos assisted them with other activities like the online homework or the in-class clicker questions. None of the BL4AL results were significant for either course when considering science learning and traditional or nontraditional learning methods. From the interviews, a possible reason for the results are that students care more about their grades than science learning. The items asked students to rate how much they agreed with the learning methods helping them with practices such as taking time to consider the effects of scientific practices and discoveries or taking new information and building on prior science knowledge. Although high-performing students may be doing well in the course, they may not apply the knowledge they have learned, and low-performing students may not do well on the exams but be interested in applying the knowledge learned.

Identification as a Scientist

Of the four components constituting student persistence (Graham et al., 2013), none of the interviewed students associated any BL affordance to their identification as a scientist. In PHY 2048 the students indicated that they needed more practice and more advanced education or experiences related to the sciences. They needed a “keep going” attitude. In CHM 2046 the students did not connect learning about science to being a scientist, but they identified as a scientist when they were in their lab course, which was a separate course to CHM 2046. Through experiences in the course students expressed that they began to think like scientists, such as thinking about the chemistry involved in cooking, yet they did not identify as scientists. The students’ experience in different science courses also influenced their views of being a scientist—

a student shared that he was a psychology major but his calling himself a scientist would not be equivalent to physicist calling himself or herself a scientist. The BL4AL results for both courses showed insignificance results of the predictor of traditional or nontraditional learning methods and students' identification as a scientist influencing the students' persistence in the sciences. As mentioned with science learning as a determinant to student persistence, the results related to identification as a scientist may also be due to the students' focus on grades rather than learning or professional identification (Kardash & Wallace, 2001). Additionally, the cases were introductory science courses that did not consist of built-in research or other experiences for professional development—Graham and associates' (2013) had built their framework on results from studies like Hatfull and associates' (2006) work with specific initiatives to include freshmen in scientific research.

Based on the conceptual framework (see Figure 2-8), the study's results indicated the stronger BL-AL influences on student persistence as defined by Graham and associates (2013) as seen in Table 5-2. As seen in the results, BL affordances for AL relate more to student motivation and student confidence rather than the identification as a scientist; the determinant of science learning required more defining.

Table 5-2. Influences of BL and AL on student persistence

Factor of student persistence	BL affordances	Influence on factor
Student motivation	PHY 2048: In-class clicker questions, Study Edge©	Positive
	CHM 2046: FTF lectures	Positive
Student confidence	Both courses: Study Edge©, exams	Both positive and negative
Science learning	Both courses: Combinations of all	Both positive and negative
Identification as a scientist	Both: None	None

Discussions

Of all the affordances, the most differently practiced between the two courses were the discussions. During the observation in PHY 2048, with a format of students' watching a teaching assistant work out problems and taking a quiz toward the end of discussion, the practice did not match the name of a "discussions" class. Emerging themes included students' questions not being answered in the discussions class, the class not supporting students to conceptualize problems, and the discussion time identified as quiz time for students. If students did not know how to solve a problem, they would receive a poor grade on the quiz. During the observation in CHM 2046, rather than attempting to have a whole class discussion, the practice was monitored problem solving through the use of the worksheets. Each student's worksheet needed to be reviewed by a teaching assistant, thereby checking for student understanding and initiating a discussion between the teaching assistant and individual student about any misunderstanding in the process of solving the given chemistry problems. Emerging themes included areas of students' weaknesses about chemistry being targeted and mentorships between students and teaching assistant being developed. In PHY 2048, the four dimensions of BL for the affordance consisted of being FTF, synchronous, middle of the spectrum between only text and rich to all senses, and somewhat interactive between people and low technology interactions; in CHM 2046, the BL affordance was FTF, synchronous, middle of the spectrum between text only and rich to all senses, and high human interactions and low technology interactions.

The students in PHY 2048 indicated discussions constrained AL components like discussions and reflection for problem solving, while students CHM 2046 indicated the affordance enabled the same AL components (Meyers & Jones, 1993).

Implications

As initially discussed in Chapter 1 and Chapter 2, although still amorphous, the development of BL and AL continues to progress within STEM education. As the government continues to channel funding into STEM education, the implications of the study's findings suggested targeted areas for research, design and implementation, and education. The study's goal was not to compare whether traditional (i.e., FTF) learning methods or nontraditional (i.e., online) learning methods are better. Thus, the implications are not framed with that type of comparison. As an investigative study, the goal was to consider the students' experiences with multidimensional BL affordances and how the affordances influence AL and student persistence. Data were gathered about the students' experiences in introductory science courses, resulting in implications for future research studies related to BL, instructional design practices for AL, and considerations for student persistence within undergraduate science education.

Implications for Research

As BL continues to evolve in higher education, with more research related to BL should be updates to the BL definition. Graham's (2006) definition of BL with four dimensions broadens the understanding of BL beyond merely being a blend of FTF synchronous and online asynchronous learning experiences—instead, a blend being on the dimensions of space, time, fidelity, and humanness. In the investigation with the PHY 2048 and CHM 2046 cases, when paired with AL, BL can be defined on spectra of space (FTF to online), time (synchronous to asynchronous), and fidelity (only text to rich to all senses) but not as simply on the spectrum of humanness (low human, high tech to high human, low tech). For example, in both courses affordances such as in-class clicker questions were found to be high technology interactions and high human interactions. The implication then—at least for BL in higher education courses with the goal of AL—is that the definition of BL should be expanded to five dimensions, in which humanness and technology are separated. The learning would be blended according to space, time, fidelity, humanness, and technology dependence.

The intent of adding a fifth dimension is not to complicate an already complex definition. Nevertheless, the addition moves the discussion regarding BL toward the ultimate goal of a more accurate and uniform communication about BL (Porter, Graham, Spring, & Welch, 2014). As BL evolves, its definition must also evolve as well. As mentioned in Chapter 2, Graham (2006) proposes that the future of BL should be a blend of technology and human interactions (see Figure 5-1).

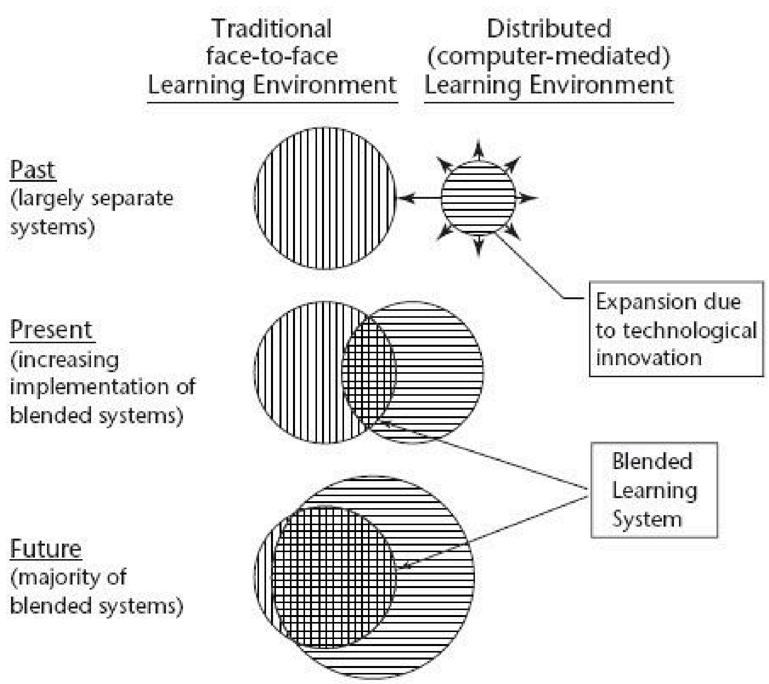

Figure 5-1. Graham's (2006) diagram of the progressive convergence of traditional FTF and distributed learning environments allowing the development of BL systems (same as Figure 2-5; used with permission from author).

Although the instructors in the cases did not use the term “blended learning” in their course development, the apparent BL affordances indicate that BL remains on track of moving toward more blended systems. More specifically, the implications of the findings from both case studies support that science education courses have become more blended in actual practice—not yet arriving at Graham’s (2006) future projection but beyond basic technological introductions with traditional lecture styles. Previous studies had compared traditional lecture-style groups to experimental groups with more BL infusion like the use of technology ports (Baepler et al., 2014), online lectures (Gonzalez, 2014), and the use of clickers (Sutherlin, Sutherlin, & Akpanudo, 2013). However, the two cases studied did not solely rely on lecture methods but also the online videos, online homework, and in-class clicker questions. The findings related to the BL4AL framework indicate that more research needs to be conducted related to BL in higher education, yet BL in higher education, including science education, is becoming more blended. Through the introduction of more technologies into blended introductory science courses, the warning would be that the mere introduction of a technology may not automatically encourage AL. As seen with the use of the LMS in both courses, the LMS organically cultivated AL practices like small group problem-solving and discussions; however, the LMS was not maximally utilized and directed for the understanding of knowledge to be tested on the high-stakes exams.

When considering BL along the lines of five dimension, the levels of BL (i.e., institutional, program, course, and activity levels) should be considered as well (Drysdale et al., 2013; Graham, 2006). The multiple-case studies examined BL at the course level, as well as investigate blending at the activity level (see Table 5-1). The implications of the findings indicate that the blending at the different levels is co-dependent but does not need to occur at a lower level (e.g., activity level) before advancing to a higher lever (e.g., course). For example, as seen in the multiple-case studies, office hours may continue to be traditional FTF, synchronous, text only, high human interactions, and low technology interactions, yet the course as a whole is considered BL. Although beyond the scope of the immediate study, the fostering of BL at the course and activity levels is co-dependent with the program and institutional levels, indicating that BL is most likely advancing at those levels as well. For example, the mini-courses for PHY 2048 required the collaborative planning and execution of three instructors in the physics program—their influence have the possibility of being infectious to the program. The course CHM 2046 consisted of multiple sections, including Petrov's. A cross-program study would indicate how BL was practiced as a whole, and the results among multiple programs will provide a more accurate depiction of BL at the institutional level for pan-institutional decisions related to the advancement of effective pedagogy, conveniences for students and instructors, increased cost effectiveness, and other improved uses of resources (Graham et al., 2005; López-Pérez, Pérez-López, & Rodríguez-Ariza, 2011; Moskal, Dziuban, & Hartman, 2013; Porter et al., 2014). A recommended study would include the investigation of BL at all levels.

Implications for Design and Implementation

The major implication related to design and implementation is that instructors may intentionally design BL affordances for AL, yet the affordances may either enable or constrain AL. Without the proper diagnosis of the constraining affordances, the productivity of BL for AL will continue to be impeded.

Parameters for the use of online videos to prepare students for lectures should be clearly defined. As discussed in the literature review, Stockwell and associates (2015) conducted a two-by-two study examining student performance based on whether the student had videos or textbook readings before class and whether the students experienced lecture only or lecture with problems solving; regarding the comparison between videos and textbook readings, students were more satisfied to receive video preparation than textbook preparation. Nevertheless, the research findings through the BL4AL framework indicate that, outside of an experimental study, students may not do either video or textbook readings to prepare for class. The time and energy demanded to create pre-lecture videos must be re-evaluated, especially if students prefer a YouTube video© or watching videos prepared by a group like Study Edge©. Simply creating a lecture video to be watched before an in-person class time for the sake of the creation of a flipped classroom can be insufficient.

Research has supported the AL course structure deviating from the traditional lecture style within the sciences, including the use of in-class clicker questions (Haak et al., 2011). Although research has shown that the use of clickers as an intervention can benefit learning of factual knowledge (Haak et al., 2011; Lin, Liu, & Chiu, 2013; Shapiro & Gordon, 2012) yet not help with the learning of conceptual knowledge (Shapiro et al, 2017), the implementation of in-class clicker questions as a BL affordance became a catalyst to encourage student discussion of course materials, thereby allowing opportunities for increased student learning, student motivation, and student confidence. Thus, in addition to assessing student knowledge, the findings implicate that peer instruction through the use of clicker questions should continue (James & Willoughby, 2011; Sullivan, 2009).

For the design of BL affordances, findings indicated that the mere addition of technology did not necessarily indicate a better learning experience. Based on the descriptions of the courses in the syllabus, one would have considered PHY 2048 to be more progressive with pre-recorded instructional videos, encouragement to ask questions during lectures, in-class clicker questions, a discussion class, and the ability to chat in the LMS to ask questions, while CHM 2046 had mainly lectures, in-class clicker questions, and the discussion class. The design of PHY 2048 seemed to indicate more BL affordances for AL; nevertheless, the implementation of CHM 2046 better impacted the students' experiences. As seen and shared about the discussion classes, students in CHM 2046 were more engaged during lecture and the discussions vibrant with students problem solving on their own or discussing problems in self-selected small groups or with one of three teaching assistants—two also undergraduates. By the end of the each class, every student had at least talked to one teaching assistant to make sure the worksheet problems were completed correctly, indicating that, although discussions included low technology, the consideration for high human interactions encouraged discussion and problem solving. As mentioned in the Implications for Research section, the impact of the use of in-class clicker questions also supported the increase of focus on human interactions with increased interactions with technology—the strength of BL being to capitalized on traditional and nontraditional learning methods.

Finally, because lectures continue to dominate the design of introductory science courses, more consideration should be devoted to the design and implementations of lectures. Based on the data collected about the PHY 2048 lectures, despite the instructor's desire to make the FTF lectures less formal and the lectures being augmented with nontraditional learning methods, half of the students interviewed indicated that the FTF lecture was a constraint to AL. In contrast, five of the six CHM 2046 students interviewed indicated that the lecture was conducive to AL. Freeman and associates (2014) conducted a meta-analysis on 225 studies about student performance between courses implementing AL and lecture-based courses; however, the study's findings from the two case studies question whether AL courses should be pitted against lecture-based courses. In addition to the blending of activities, the role and the personality of the instructor can also enable AL. Rather than merely researching the personalities of students, the findings implicate future studies should also focus on the instructors' personality and relatability to students in introductory science courses, thereby strengthening AL strategies to improve lecture-based instruction in large-enrollment undergraduate science courses (e.g., Mazur, 2009; Watkins & Mazur, 2013).

Implications for Education

Related to science education, the findings related to the BL4AL framework implicate that (1) Graham and associate's (2013) student persistence framework should be re-evaluated for introductory science courses and (2) BL experiences for AL are no longer confined to instructor-led courses but are also heavily influenced by third parties like online publishers and tutoring services like Study Edge©—essentially becoming an informal course taken by students.

Students in both courses expressed the lack of experiences a scientist would have and the differences between being a student versus being a scientist—the student being on the opposite end of the spectrum compared to a scientist. As presented in Chapter 2, previous research has shown that students' experiences with AL and its manifestations like inquiry-based learning have encouraged them to identify more with being scientists (Crippen & Archambault, 2012). However, despite Graham and associates' (2013) argument in favor of students' identification as a scientist for student persistence, the framework should be adjusted for students in introductory science courses. As Linn, Palmer, Baranger, Gerard, and Stone (2015) indicate in their study with undergraduate research experiences, first-year students experience "slow enculturation into scientific practices," thereby making the whole scientific process more difficult to understand. Rather than focusing on the encouragement of students' to identify as a scientists, the shift in thought for research and funding for research in introductory science courses would focus on students' motivation and confidence in the set up for more in-depth scientific learning (e.g., setting up experiments and collecting data; Linn et al., 2015).

The results of the BL4AL survey also imply that the students' motivation and confidence with traditional learning methods within a course predict whether they will persist in the sciences, indicating that students have not yet esteemed nontraditional learning methods as predictors to whether they will continue in the sciences. As the Department of Education continues to financially support the enrichment of STEM curricula, the focus should be not only on changes with instructors but also on the perspectives of students for a culture change from traditional learning methods to nontraditional learning methods.

In both introductory science courses studied, the online homework was supported by a third-party publisher. Although the CHM 2046 instructor handpicked questions in the system to match her exams, students still identified a disconnect between their online homework and the exam. A similar quandary would have existed if the instructors chose textbook questions to be homework, but with online homework, whether stemming from the publishers or from the instructors, considerations should be made about the alignment between content and assessments and about the students' experiences of answering questions online versus using a writing utensil, paper, and a Scantron©. Findings from the multiple-case study imply that expectations for the online homework and the exam tend to not align, particularly in the instances in which students' scores were lowered due to incorrectly inputting answers in comparison to the bubbling of correct multiple-choice answers for the exams.

The students' reporting of Study Edge© as motivating and confidence-building factors was an unforeseen result to the research. More research is needed concerning the phenomenon highlighting that students paid extra money in addition to their tuition for similar BL affordances offered by the course (e.g., practice exams, online videos, FTF lectures) and that the extra cost motivated students to continue their studies in the course. Implications from research on student usage of outside tutoring services may influence future instructional practices and possibly even business models as to what BL affordances the university will provide versus the provisions of a third party.

Limitations

The design of the study was to conduct case study research with an embedded survey component. Although six students interviewed for each case was adequate for multiple-case studies (Yin, 2014), a larger sample of the BL4AL survey respondents would have strengthened the power in the statistical analyses.

Additionally, the breakdown of PHY 2048 into three mini-courses did not match with the semester-long CHM 2046. Although for the purpose and design of the study the comparison between the PHY 2048 mini-course and CHM 2046 was appropriate, future studies may review courses with more similar schedules.

As mentioned in Chapter 3, the researcher acknowledged the possibility of rival explanation to the results: investigator bias, direct rival, rival theory, super rival, and societal rival (Yin, 2014). The researcher was a graduate student in educational technology and an instructional designer for the university, creating investigator bias during the study. For example, in the data analysis and reporting, the researcher reviewed the course designs and educational tools used and favored one course with a seemingly more purposeful design. The general investigator bias is detailed in the researcher’s positionality statement (Appendix G). Rather than basing conclusions about BL affordances, AL, and student persistence on personal opinions, the researcher based conclusions on the data collected from the interviews, documentations, observations, and surveys.

The concern about direct rivals was that the individual BL affordance could be equally effective on its own versus being a BL affordance. However, after the data collection and analysis, findings indicated that the use of each BL affordance was at least woven into the use of another BL affordance. Each affordance had its own characteristics, function, and influence, but no one influenced AL and student persistence compared to the experience of multiple affordances. For example, how confident the student was in the course was not solely based on exams but also the experiences in the FTF lectures, with the online homework, and self-discovered on resources.

More research related to BL is needed to investigate if and how other theories explain the influences of BL on AL and student persistence. This study proposed that the combination of BL affordances influences the implementation of AL, and the relationship between the two influences students' perspectives of student persistence, at least the factors of motivation, confidence, and science learning. The study also lends support to a possible super rival that, instead of BL affordances, the influence of the instructor's persona as an effective teacher, communicator, and scientist role model may propel students toward AL and to remain in the sciences—nevertheless, the BL affordances would continue to be needed to support the instructor. Finally, because of the localized focus within the cases, the rival of social trends did not influence the study's findings and report.

Although the use of BL4AL provided insight to students' perspectives on the blending of FTF and online learning methods relative to student persistence, more research is needed concerning the use of the BL4AL. Analysis of the two courses revealed insights about student motivation and student confidence; however, the BL4AL instrument should be administered to larger populations to better understand its construct validity. Although examples of traditional learning methods and nontraditional learning methods were provided for the participants in the survey's directions, it is uncertain what they considered traditional and nontraditional learning methods as they completed the survey. For example, it is uncertain how students sorted, if they sorted, Study Edge© under traditional learning methods or nontraditional learning methods. Additionally, more research should be conducted to make the instrument more parsimonious.

Conclusion

With the emergence of diverse technologies and the transformation of physical and virtual campuses across the United States, conversations will continue to include the use of “blended learning,” “active learning,” and “student persistence in STEM education.” In addition to Means and associates’ (2010) meta-analysis that BL had a larger effect size than purely FTF or online learning in the K-12 environments, more research should be conducted on the influences of BL in higher education. To reiterate Garrison and Vaughan’s (2008) prediction, “[w]hen blended learning is well understood and implemented, higher education will be transformed in a way not seen since the expansion of higher education in the late 1940s” (p. x). In present-day research about education, BL, AL, and student persistence remain amorphous in definition and in practice, and their importance continues to be negotiated in introductory-level science courses at universities—oftentimes in courses and in departments with deeply rooted practices of lecture-styled teaching. It is the hope of the researcher that the labor to provide a conceptual framework for BL affordances on AL and student persistence in introductory science courses will contribute to better conversations, better decisions, and better practices in the evolution of education.

APPENDIX A
INTERVIEW PROTOCOL FOR INSTRUCTORS

Interviewee Background Questions

1. What courses have you taught?
2. How long have you been teaching?

Within the context of face-to-face learning and online learning in your course (based Graham, 2006):

Fidelity

1. What is the present course that you teach like, particularly what materials and methods are being used?
2. How does the course content appeal to the students' senses?

Space

3. What are the work / teaching spaces like?
4. What student work is conducted online?
5. What student work is conducted face to face?
6. If there are any, what student experiences require simultaneous online and face-to-face work?

Time

7. How long are students required to work in an online environment?
8. How long are students required to work in a face-to-face environment?

Humanness

9. How many instructors are involved with the course development and teaching oversight?
10. What specifically are your responsibilities with the course?
11. How much time do you devote to course preparation and maintenance?
12. How much time do you spend with students?

Active learning components (based on Meyers and Jones, 1993)

13. What are your expectations for student performance in the course?
14. What are instructional strategies you use?
15. What teaching resources do you use?

Persistence-focused questions (based on Graham et al., 2013)

16. How confident do you think students are?
17. How motivated do you think students are?
18. How can students identify as scientists in the course?
19. What type of research opportunities do the students have in the course?

APPENDIX B
INTERVIEW PROTOCOL FOR STUDENTS

(in person or via video chat for an hour)

Interviewee Background Questions

1. What year are you?
2. What is your major?
3. What science courses have you taken so far?

Within the context of face-to-face learning and online learning in your course (based Graham, 2006):

Fidelity

1. What is [course name] like?
2. How does the course content appeal to your senses?

Space

3. What are the learning spaces like?
4. What work is conducted online?
5. What work is conducted face to face?
6. If there are any, what experiences require simultaneous online and face-to-face work?

Time

7. How much time do you spend online for the course?
8. How much time do you spend in a face-to-face environment for the course?

Humanness

9. How much time do you spend with instructors? With other students?
10. What specifically are your responsibilities with the course?

Active learning components (based on Meyers and Jones, 1993)

11. What specifically are your responsibilities with the course?
12. What are your expectations for your performance in the course?
13. What are learning strategies you use?
14. What learning resources do you use?

Persistence-focused questions (based on Graham et al., 2013)

15. Why are you taking the course?
16. Do you feel confident in the course? Why?
17. Do you feel motivated in the course? Why?
18. How do you identify as a scientist in the course?
19. What type of research opportunities do you have in the course?

APPENDIX C
EXAMPLE OF PORTAAL OBSERVATION LOG (RUBRIC)

Observer ______________ Date of Observation: ________________________ Page ___ of _____

School: ________________ Course: _______________ Instructor: _________________ Session Date: ____________

1. Start of Class (Min:Sec): _______________ 2. End of Class (Min:Sec): _____________

	Observations:	**Activity ___**	**Activity ___**	**Activity ___**	**Activity ___**	**Activity ___**
	3. Start of introduction (min:sec):					
	4. End of Introduction (min:sec):					
	5. Explicitly encourages students to focus on logic:	Y N	Y N	Y N	Y N	Y N
	6. Explicitly encourages students to use prior knowledge:	Y N	Y N	Y N	Y N	Y N
	7. Explicitly reminds students that errors are natural and useful/educational	Y N	Y N	Y N	Y N	Y N
	8. Bloom Level of Activity: Higher order, (H) Lower order (L), Course Logistics (C), Opinion Poll (O)	H L C O	H L C O	H L C O	H L C O	H L C O
	9. Form of Activity: Clicker Q (C), Worksheet (W), etc.					
	10. Instances of explicit positive feedback or encouragement: Directed towards entire class (C), Directed towards individual students (S)	C: S:	C: S:	C: S:	C: S:	C: S:
	11. Instances of praise or encouragement referencing effort or improvement:					
	12. Instances of explicit negative feedback: Directed towards entire class (C), Directed towards individuals (S)	C: S:	C: S:	C: S:	C: S:	C: S:
	13. Explicitly encourages students to focus on logic:	Y N	Y N	Y N	Y N	Y N
	14. Explicitly encourages students to use prior knowledge:	Y N	Y N	Y N	Y N	Y N
	15. Explicitly reminds students that errors are natural and useful/educational	Y N	Y N	Y N	Y N	Y N
	16. Total number of students heard:	V: R: C:	V: R: C:	V: R: C:	V: R: C:	V: R: C:
	17. Number students who explain logic behind their response.					
SE: Iteration 1	18. Start (Min:Sec):					
SE: Iteration 1	19. End (min:sec):					
SE: Iteration 1	20. Question discussed: Individually (I), Small Groups (S), Student Volunteers (V), Random Call (R), Cold Call (C)	I S V R C	I S V R C	I S V R C	I S V R C	I S V R C
	21. Start (min:sec):					
	22. End (min:sec):					
	23. Is the correct answer in anyway indicated between iterations?	Hint/Hist N	Hint/Hist N	Hint/Hist N	Hint/Hist N	Hint/Hist N
	24. Question discussed: Individually (I), Small Groups (S), Student Volunteers (V), Random Call (R), Cold Call (C)	I S V R C	I S V R C	I S V R C	I S V R C	I S V R C

Observer ____________Date of Observation: ______________________ Page ___ of _____

School: _______________ Course: ______________ Instructor: ________________ Session Date: ___________

	Observations:	Activity ___	Activity ___	Activity ___	Activity ___	Activity ___
SE: Iteration 3	25. Start (min:sec):					
	26. End (min:sec):					
	27. Is the correct answer in anyway indicated between iterations?	Hint/Hist N	Hint/Hist N	Hint/Hist N	Hint/Hist N	Hint/Hist N
	28. Question discussed: Individually (I), Small Groups (S), Student Volunteers (V), Random Call (R), Cold Call (C)	I S V R C	I S V R C	I S V R C	I S V R C	I S V R C
	29. Start of Activity Debrief (min:sec):					
	30. End of Activity Debrief (min:sec):					
	31. People involved in Debrief: Instructor only (I), Student Volunteers (V), Random Call (R), Cold Call (C)	I V R C	I V R C	I V R C	I V R C	I V R C
	32. Total Number of students heard:	V: R: C:	V: R: C:	V: R: C:	V: R: C:	V: R: C:
	33. Is correct answer explained?	Y N NA	Y N NA	Y N NA	Y N NA	Y N NA
	34. Number of alternatives discussed:					
	35. Number students who explain logic behind their response:					
	36. Instances of explicit positive feedback or encouragement from instructor: Directed towards entire class (C), Directed towards individual students (S)	C: S:	C: S:	C: S:	C: S:	C: S:
	37. Instances of praise or encouragement referencing effort or improvement:					
	38. Instances of explicit negative feedback/responses from instructor: Directed towards entire class (C), Directed towards individual students (S)	C: S:	C: S:	C: S:	C: S:	C: S:
	39. Explicitly reminds students that errors are natural and useful/educational	Y N	Y N	Y N	Y N	Y N
	40. Is activity graded: For Correctness (C), For Participation (P), No Points for Participation (N)	C P N	C P N	C P N	C P N	C P N
ANY TIME	41. General Comments:					

APPENDIX D
CONVERSION CHART: OBSERVATIONS TO PORTAAL SCORES (WENDEROTH, 2014)

How to convert observations in rubric to a measure of each element:

		How Element Observed in the Classroom:	PORTAAL Rubric Observations that could be Involved:	Steps for commuting summary measure:
Dimension 1: Practice				
Elements	**P1**. Frequent Practice	Minutes any student has the possibility of talking through content in class	1, 2, 18, 19, 21, 22, 25, 26, 29,30	1. Total Time Students Active per Activity = 1st iteration of engagement (#19-18) + 2nd iteration(22-21) + third iteration(26-25) + Debrief*(30-29) *include only if V, R, or C is circled in #31 2. Sum across activities for the sessions 3. Divide by total class time to get % class time students active. 4. Average across the 3 sessions
	P2. Alignment of Practice with Assessment	In-class practice questions of same Bloom level as Assessments *(*Requires access to exams*)*	8	1. Count number of activities were H circled in #8 for each session 2. Divide this number by total number of activities to get % activities that involve higher order skills. 3. Average % across the 3 sessions 4. Categorize exam questions as H or L 5. Determine % Exam question H 6. Compare exams and in class questions

	P3. Distributed practice	% of activities where instructor reminds students to use prior knowledge	6, 14	1. Count number of activities where Y is circled for 6 or 14. 2. Divide this number by total number of activities to get a % of activities. 3. Average % across three sessions.
	P4. Immediate Feedback	% activities instructor hears individual student answers and has an opportunity to respond	20, 24, 28, 31	1. Count number of activities where V, R, or C is circled for #20, 24, 28, or 31. 2. Divide this number by the total number of activities to get a percent. 3. Average % across three sessions.
Dimension 2: Logic Development				
Elements	**L1**. Frequent opportunities to practice higher order skills in class.	% Activities that problem requires students use higher order skills (application, analysis, evaluation, synthesis)	8	1. Count number of activities were H circled in #8 for each session. 2. Divide this number by total number of activities to get % activities HO. 3. Average % across the 3 sessions
	L2. Prompt student to explain/defend their answers.	% Activities students reminded to use logic before student engagement.	5, 13	1. Count number of activities where Y is circled for 5 or 13. 2. Divide this number by total number of activities to get a % of activities 3. Average % across three sessions.
	L3. Allow students time to think before they discuss answers.	% Activities students explicitly given time to think alone before have to talk in groups or in front of class (this can include answering clicker questions on their own) during	20	1. Count number of activities where I is circled for #20. 2. Divide this number by total number of activities to get a % of activities. 3. Average % across three sessions.

		student engagement.		
	L4. Students explain their answers to their peers.	% Activities students work in small groups during student engagement.	20, 24, 28	1. Count number of activities where S is circled for either 20, 24, or 28. 2. Divide this number by total number of activities to get a % of activities. 3. Average % across three sessions.
	L5. Students solve problems without hints	% activities answer not hinted at between iterations of student engagement.	23, 27	1. Count number of activities were N is circled for #23 or 27 in one class session. 2. Divide this by the total number of activities in session to get a % of activities. 3. Average % across three sessions
	L6. Students explain logic behind their answers in front of whole class so instructor can hear and respond to their ideas.	% Activities students share their logic in front of whole class during an iteration of student engagement or debrief	Same as P4	
	L7. Logic behind correct answer explained	% Activities where correct answer is explained	33	1. Count number of activities where Y is circled for #33 in one class session. 2. Divide this by the total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
	L8. Logic behind why incorrect answers incorrect explained	% Activities where alternative answers are discussed during debrief.	34	1. Count number of activities where #34 has a number listed greater than zero. 2. Divide this by the total number of activities

				in that session to get a % of activities. 3. Average % across all three sessions.
Dimension 3: Accountability				
Elements	A1. Activities worth course points	% Activities worth course points *(*Requires a syllabus or talking with the instructor*)*	40	1. Count number of activities where C or P is circled for #40. 2. Divide this by the total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
	A2. Activities involve small group work so more students have opportunity to participate	% Activities with small group work during student engagement stages.	Same as L4	
	A3. Avoid volunteer bias by using cold or random call	% Activities were cold or random call used during student engagement or debrief stages.	20, 24, 28, 31	1. Count number of activities where R or C is circled for either 20, 24, 28, or . 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
Dimension 4: Apprehension Reduction				
Elements	R1. Give students practice participating by enforcing participation through cold/random call	% Activities with Random or Cold Calling used during student engagement or debrief	Same as A3	
	R2. Student Confirmation: Provide praise to whole class for their work	% Debriefs and engagements where class received positive feedback and/or encouragement	10, 35	1. Count number of activities where a number greater than 0 is listed next to the C: for #10 or #35. 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.

	R3. Student Confirmation: Provide praise/encouragement to individual students	% student responses with positive feedback and/or encouragement	10, 35	1. Count number of activities where a number greater than 0 is listed next to the S: for #10 or #35. 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
	R4. Student Confirmation: Do not belittle/insult student responses	% student responses that do not receive negative feedback	12, 38	1. Count number of activities where either a 0 or no numbers are listed next to S: or C: for #12 or #38 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
	R5. Error Framing: Emphasize errors natural/instructional	% Activity where instructor reminds students that errors are nothing to be afraid of during introduction or student engagement periods.	7, 15, 39	1. Count number of activities where Y is circled for either 7 15, or 39. 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.
	R6. Emphasize hard work over ability	% Activities instructor praises student effort or improvement	11, 37	1. Count number of activities where there are counts in either 11 or 37. 2. Divide this number by total number of activities in that session to get a % of activities. 3. Average % across all three sessions.

APPENDIX E
JOHNSON AND MCCLURE'S (2004) CLES 2(20)

Response choices for all items are:
A Almost Always
B Often
C Sometimes
D Seldom
E Almost Never

Learning About the World (Personal Relevance)
In this class . . .
1. Students learn about the world inside and outside of school.
2. New learning relates to experiences or questions about the world inside and outside of school.
3. Students learn how science is a part of their inside- and outside-of-school lives.
4. Students learn interesting things about the world inside and outside of school.

Learning About Science (Uncertainty)
In this class . . .
5. Students learn that science cannot always provide answers to problems.
6. Students learn that scientific explanations have changed over time.
7. Students learn that science is influenced by people's cultural values and opinions.
8. Students learn that science is a way to raise questions and seek answers.

Learning to Speak Out (Critical Voice)
In this class . . .
9. Students feel safe questioning what or how they are being taught.
10. I feel students learn better when they are allowed to question what or how they are being taught.
11. It's acceptable for students to ask for clarification about activities that are confusing.
12. It's acceptable for students to express concern about anything that gets in the way of their learning.

Learning to Learn (Shared Control)
In this class . . .
13. Students help me plan what they are going to learn.
14. Students help me to decide how well they are learning.
15. Students help me to decide which activities work best for them.
16. Students let me know if they need more/less time to complete an activity.

Learning to Communicate (Student Negotiation)
In this class . . .
17. Students talk with other students about how to solve problems.
18. Students explain their ideas to other students.
19. Students ask other students to explain their ideas.
20. Students are asked by others to explain their ideas.

APPENDIX F
BLENDED LEARNING FOR ACTIVE LEARNING (BL4AL)

Demographic Questions

1. What year are you? (Freshman, Sophomore, Junior, Senior, Graduate)
2. What is your major? (Biology, Chemistry, Physics, Engineering, Other [with write-in option])
3. Are you pre-med? (Yes, No)
4. What gender do you identify with? (Female, Male, Transgender Female, Transgender Male, Gender Variant / Non-Conforming, Not Listed [with write-in option])
5. Please specify your ethnicity (Check all that apply: Asian or Pacific Islander, Black or African American, Hispanic or Latino, Native American or American Indian, White or Caucasian, Other [with write-in option])
6. How many other science courses (for example, biology, chemistry) have you taken? (0, 1-2, 3-4, 5+)
7. What is your self-predicted grade for this course? (A+, A, A-, B+, B, B-, C+, C, C, Below C-)

Directions

Indicate how much you agree to **traditional** class practices and to **nontraditional** class practices affecting you, as seen in the following statements.

Traditional class experiences: Examples include use of pen and paper, in-class lectures and discussions, physical textbook readings, and paper exams

Nontraditional class experiences: Examples include use of online apps, online communication, online activities, virtual simulations, online assignments, and clickers

Likert Scale: 1 Strongly Agree, 2 Agree, 3 Neutral, 4 Disagree, 5 Strongly Disagree

Motivation (Persistence component 1, per Graham et al., 2013)
Traditional class experiences have helped me:
Nontraditional class experiences have helped me:
1. To consider the social impact that science can make.
[Humanness (Graham, 2006); basic elements (Meyers & Jones, 1993)]
2. To have more of a desire to solve a scientific question for answers on my own.
[Time (Graham, 2006); basic elements (Meyers & Jones, 1993)]
3. To look for other learning resources that my instructor has not suggested.
[Fidelity (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.
[Time (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
5. To be interested in learning more about science outside of class requirements.
[Space (Graham, 2006); teaching resources (Meyers & Jones, 1993)]

6. To engage in question-asking, responses, or discussions with my instructor and/or peers.
[Humanness (Graham, 2006); learning strategies (Meyers & Jones, 1993)]
7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation).
[Space (Graham, 2006); learning strategies (Meyers & Jones, 1993)]
8. To try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.
[Fidelity (Graham, 2006); learning strategies (Meyers & Jones, 1993)]

Confidence (Persistence component 2, per Graham et al., 2013)
1. To feel comfortable sharing science ideas in class or online.
[Space (Graham, 2006); basic elements, (Meyers & Jones, 1993)]
2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.
[Humanness (Graham, 2006); basic elements, (Meyers & Jones, 1993)]
3. To use more than one sense to learn new science information.
[Fidelity (Graham, 2006); basic elements, (Meyers & Jones, 1993)]
4. To notice in my daily life through different senses what I learned in my science class.
[Fidelity (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
5. To feel confident in finding resources to help my learning.
[Space (Graham, 2006); teaching resources, (Meyers & Jones, 1993)]
6. To feel comfortable enough to take risks and to make possible mistakes.
[Time (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
7. To feel confident when taking science quizzes or tests.
[Humanness (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]
8. To effectively manage my time to learn the materials for my science class.
[Time (Graham, 2006); learning strategies (Meyers & Jones, 1993)]

Science Learning (Persistence component 3, per Graham et al., 2013)
1. To take time to consider the effects of scientific practices and discoveries.
[Time (Graham, 2006); basic elements (Meyers & Jones, 1993)]
2. To share what I am learning with my instructor or peers.
[Humanness (Graham, 2006); basic elements (Meyers & Jones, 1993)]
3. To take new information and build upon prior science knowledge.
[Time (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
4. To obtain the necessary information or equipment for science learning.
[Space (Graham, 2006); teaching resources, (Meyers & Jones, 1993)]
5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.
[Fidelity (Graham, 2006); teaching resources, (Meyers & Jones, 1993)]
6. To raise questions and seek answers when learning about science.
[Humanness (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]
7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).

[Fidelity (Graham, 2006); learning strategies (Meyers & Jones, 1993)]
8. To have adequate space to take the necessary steps to solve a scientific question.
[Space (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]

Identification as a Scientist (Persistence component 4, per Graham et al., 2013)
1. To use more than one of my senses to understand present scientific theory.
[Fidelity (Graham, 2006); basic elements (Meyers & Jones, 1993)]
2. To have adequate time to journal or write down what I have learned.
[Time (Graham, 2006); basic elements (Meyers & Jones, 1993)]
3. To hear or read about what today's scientists are practicing.
[Fidelity (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
4. To access science experts who have projects that I can join if I asked.
[Humanness (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
5. To take the time to review and challenge the present scientific theory I have learned.
[Time (Graham, 2006); teaching resources (Meyers & Jones, 1993)]
6. To have the necessary space to work with others to solve scientific problems.
[Space (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]
7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).
[Humanness (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]
8. To test science knowledge through discussions, assignments, or any other class activity.
[Space (Graham, 2006); learning strategies, (Meyers & Jones, 1993)]

Question: I am more motivated to study the sciences after taking this course. (1 Strong Agree to 5 Strongly Disagree)

Question: Will you take another course after this one? (Yes, Maybe, No)

APPENDIX G
RESEARCHER'S POSITIONALITY STATEMENT

The researcher is an instructional designer and team leader for a university's instructional design unit that focuses on an undergraduate online program and distance and continuing education. Her instructional design experience began during her studies to be a teacher, having earned a master's in education and having taught secondary students and undergraduates. Thus, her perspectives stem from her experiences in instructional design and in the classroom.

Epistemologically, the researcher advocates for constructivism but gravitates toward pragmatism, supporting the explanation of pragmatism as "the doctrine that 'truths' are values and that 'realities' are arrived at by processes of valuation, and that consequently our 'facts' are not independent of our 'truths,' nor our 'truths' of our 'goods'" (Schiller, 1905, p. 237). In her studies, the researcher focuses on how information can be practical or applied within social and cultural contexts.

APPENDIX H
SAMPLE OF AUDIT TRAIL

Feb 2017

Observed physics professor’s larger lecture (see notes)

Interviewed TA: although decided to focus research attention to instructors and students, wanted TA perspectives in case I needed to look at other course materials or practices; “discussion” courses with the TA also constitute course experience for students / discussions are different than for-credit labs

March 2017
Survey administered to students through Qualtrics. I coordinated with instructor for announcements and extra credit.
Observed smaller physics lecture (see notes).

Interviewed students mid-March so that they would have sufficient time with Acosta before interview. The students were interviewed during the week they were preparing for the 2nd exam, capping Acosta’s teaching time.

April and May 2017
Recordings sent out for transcription and returned.

July 2017

When analyzing the data, I decided to focus on one case at a time so that I wouldn’t want to cross-case analyze before reviewing each case first. I started out with Physics because the interview and survey data had to be collected earlier because of the ending of the mini-course in March.

I completed an initial coding for the professor’s interview. The professor provided descriptive information about the design and implementation of the course. Some of what he says provides for some seeds for codes.

Decided to code the interviews with high performing students first because they may be similar to the instructor’s comments since they do well in his designed course. Moving to the lower performing students may show how the perspectives change.

In interviews students were predicting final grade, I understand students may be over optimistic, pessimistic, or accurately predicting their grades. The student’s answer is just used as a help to see how confident they are in their abilities.

APPENDIX I
BL4AL FACTOR LOADINGS AND STANDARD ERRORS OF FACTOR LOADINGS

Table I-1. Factor loadings and standard errors of factor loadings for motivation—traditional learning methods in PHY 2048

Items	Factor loading	S.E.
SM1. To consider the social impact that science can make.	-.02	.05
SM2. To have more of a desire to solve a scientific question for answers on my own.	.50	.13
SM3. To look for other learning resources that my instructor has not suggested.	.64	.06
SM4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.	.65	.07
SM5. To be interested in learning more about science outside of class requirements.	.25	.09
SM6. To engage in question-asking, responses, or discussions with my instructor and/or peers.	.42	.08
SM7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation.	.65	.08
SM8. I try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.	.69	.08

Table I-2. Factor loadings and standard errors of factor loadings for motivation—traditional learning methods in CHM 2046

Items	Factor loading	S.E.
SM1. To consider the social impact that science can make.	.73	.05
SM2. To have more of a desire to solve a scientific question for answers on my own.	.66	.06
SM3. To look for other learning resources that my instructor has not suggested.	.58	.07
SM4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.	.65	.06
SM5. To be interested in learning more about science outside of class requirements.	.87	.05
SM6. To engage in question-asking, responses, or discussions with my instructor and/or peers.	.68	.05
SM7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation.	.84	.05
SM8. I try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.	.73	.06

Table I-3. Factor loadings and standard errors of factor loadings for motivation—nontraditional learning methods in PHY 2048

Items	Factor loading	S.E.
SM1. To consider the social impact that science can make.	.18	.09
SM2. To have more of a desire to solve a scientific question for answers on my own.	.20	.10
SM3. To look for other learning resources that my instructor has not suggested.	.66	.07
SM4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.	.73	.07
SM5. To be interested in learning more about science outside of class requirements.	.50	.09
SM6. To engage in question-asking, responses, or discussions with my instructor and/or peers.	.66	.09
SM7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation.	.81	.07
SM8. I try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.	.57	.08

Table I-4. Factor loadings and standard errors of factor loadings for motivation—nontraditional learning methods in CHM 2046

Items	Factor loading	S.E.
SM1. To consider the social impact that science can make.	.70	.05
SM2. To have more of a desire to solve a scientific question for answers on my own.	.77	.05
SM3. To look for other learning resources that my instructor has not suggested.	.64	.06
SM4. To take my time to review learning resources (like science journals, YouTube videos, Wikipedia, etc.) for more understanding about science topics.	.68	.06
SM5. To be interested in learning more about science outside of class requirements.	.85	.05
SM6. To engage in question-asking, responses, or discussions with my instructor and/or peers.	.80	.06
SM7. To consider how science works in different environments or situations (such as outdoors or indoors, at work, or on vacation.	.75	.05
SM8. I try to use more than one of my senses (i.e., sight, hearing, touch, taste, and smell) when solving science problems.	.77	.06

Table I-5. Factor loadings and standard errors of factor loadings for confidence—traditional learning methods in PHY 2048

Items	Factor loading	S.E.
SC1. To feel comfortable sharing science ideas in class or online.	.31	.10
SC2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.	.36	.10
SC3. To use more than one sense to learn new science information.	.76	.08
SC4. To notice in my daily life through different senses what I learned in my science class.	.62	.08
SC5. To feel confident in finding resources to help my learning.	.59	.08
SC6. To feel comfortable enough to take risks and to make possible mistakes.	.52	.09
SC7. To feel confident when taking science quizzes or tests.	.46	.08
SC8. To effectively manage my time to learn the materials for my science class.	.67	.08

Table I-6. Factor loadings and standard errors of factor loadings for confidence—traditional learning methods in CHM 2046

Items	Factor loading	S.E.
SC1. To feel comfortable sharing science ideas in class or online.	.77	.05
SC2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.	.71	.05
SC3. To use more than one sense to learn new science information.	.67	.06
SC4. To notice in my daily life through different senses what I learned in my science class.	.64	.06
SC5. To feel confident in finding resources to help my learning.	.65	.05
SC6. To feel comfortable enough to take risks and to make possible mistakes.	.75	.06
SC7. To feel confident when taking science quizzes or tests.	.68	.05
SC8. To effectively manage my time to learn the materials for my science class.	.66	.06

Table I-7. Factor loadings and standard errors of factor loadings for confidence—nontraditional learning methods in PHY 2048

Items	Factor loading	S.E.
SC1. To feel comfortable sharing science ideas in class or online.	.20	.10
SC2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.	.09	.08
SC3. To use more than one sense to learn new science information.	,75	.07
SC4. To notice in my daily life through different senses what I learned in my science class.	.81	.07
SC5. To feel confident in finding resources to help my learning.	.71	.07
SC6. To feel comfortable enough to take risks and to make possible mistakes.	.71	.07
SC7. To feel confident when taking science quizzes or tests.	.69	.08
SC8. To effectively manage my time to learn the materials for my science class.	.66	.08

Table I-8. Factor loadings and standard errors of factor loadings for confidence—nontraditional learning methods in CHM 2046

Items	Factor loading	S.E.
SC1. To feel comfortable sharing science ideas in class or online.	.68	.05
SC2. To feel comfortable having back-and-forth discussions about science topics or to collaborate with my peers.	.69	.05
SC3. To use more than one sense to learn new science information.	.77	.06
SC4. To notice in my daily life through different senses what I learned in my science class.	.69	.06
SC5. To feel confident in finding resources to help my learning.	.74	.05
SC6. To feel comfortable enough to take risks and to make possible mistakes.	.75	.06
SC7. To feel confident when taking science quizzes or tests.	.67	.06
SC8. To effectively manage my time to learn the materials for my science class.	.69	.06

Table I-9. Factor loadings and standard errors of factor loadings for science learning—traditional learning methods in PHY 2048

Items	Factor loading	S.E.
SL1. To take time to consider the effects of scientific practices and discoveries.	.23	.09
SL2. To share what I am learning with my instructor or peers.	.24	.09
SL3. To take new information and build upon prior science knowledge.	.67	.06
SL4. To can obtain the necessary information or equipment for science learning.	.56	.07
SL5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.	.50	.07
SL6. To raise questions and seek answers when learning about science.	.58	.07
SL7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).	.54	.07
SL8. To have adequate space to take the necessary steps to solve a scientific question.	.62	.07

Table I-10. Factor loadings and standard errors of factor loadings for science learning—traditional learning methods in CHM 2046

Items	Factor loading	S.E.
SL1. To take time to consider the effects of scientific practices and discoveries.	.66	.06
SL2. To share what I am learning with my instructor or peers.	.58	.06
SL3. To take new information and build upon prior science knowledge.	.58	.05
SL4. To can obtain the necessary information or equipment for science learning.	.65	.05
SL5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.	.71	.05
SL6. To raise questions and seek answers when learning about science.	.71	.06
SL7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).	.67	.06
SL8. To have adequate space to take the necessary steps to solve a scientific question.	.71	.06

Table I-11. Factor loadings and standard errors of factor loadings for science learning—nontraditional learning methods in PHY 2048

Items	Factor loading	S.E.
SL1. To take time to consider the effects of scientific practices and discoveries.	.25	.09
SL2. To share what I am learning with my instructor or peers.	.27	.08
SL3. To take new information and build upon prior science knowledge.	.71	.06
SL4. To can obtain the necessary information or equipment for science learning.	.64	.08
SL5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.	.70	.07
SL6. To raise questions and seek answers when learning about science.	.64	.08
SL7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).	.66	.08
SL8. To have adequate space to take the necessary steps to solve a scientific question.	.76	.07

Table I-12. Factor loadings and standard errors of factor loadings for science learning—nontraditional learning methods in CHM 2046

Items	Factor loading	S.E.
SL1. To take time to consider the effects of scientific practices and discoveries.	.76	.05
SL2. To share what I am learning with my instructor or peers.	.75	.05
SL3. To take new information and build upon prior science knowledge.	.63	.06
SL4. To can obtain the necessary information or equipment for science learning.	.73	.05
SL5. To access learning resources (like museums, experiments, videos, etc.) that require me to use more than one of my senses for understanding about science topics.	.72	.06
SL6. To raise questions and seek answers when learning about science.	.76	.05
SL7. To practice simulating scientific scenarios (such as simulating a scientific interaction, a principle, or an experiment).	.81	.05
SL8. To have adequate space to take the necessary steps to solve a scientific question.	.68	.06

Table I-13. Factor loadings and standard errors of factor loadings for identification as a scientist—traditional learning methods in PHY 2048

Items	Factor loading	S.E.
IS1. To use more than one of my senses to understand present scientific theory.	.27	.11
IS2. To have adequate time to journal or write down what I have learned.	.25	.10
IS3. To hear or read about what today's scientists are practicing.	.62	.07
IS4. To access science experts who have projects that I can join if I asked.	.48	.09
IS5. To take the time to review and challenge the present scientific theory I have learned.	.57	.08
IS6. To have the necessary space to work with others to solve scientific problems.	.71	.08
IS7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).	.79	.08
IS8. To test science knowledge through discussions, assignments, or any other class activity.	.60	.07

Table I-14. Factor loadings and standard errors of factor loadings for identification as a scientist—traditional learning methods in CHM 2046

Items	Factor loading	S.E.
IS1. To use more than one of my senses to understand present scientific theory.	.61	.06
IS2. To have adequate time to journal or write down what I have learned.	.65	.06
IS3. To hear or read about what today's scientists are practicing.	.84	.05
IS4. To access science experts who have projects that I can join if I asked.	.86	.06
IS5. To take the time to review and challenge the present scientific theory I have learned.	.87	.05
IS6. To have the necessary space to work with others to solve scientific problems.	.66	.06
IS7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).	.86	.05
IS8. To test science knowledge through discussions, assignments, or any other class activity.	.56	.06

Table I-15. Factor loadings and standard errors of factor loadings for identification as a scientist—nontraditional learning methods in PHY 2048

Items	Factor loading	S.E.
IS1. To use more than one of my senses to understand present scientific theory.	.02	.03
IS2. To have adequate time to journal or write down what I have learned.	.22	.08
IS3. To hear or read about what today's scientists are practicing.	.64	.07
IS4. To access science experts who have projects that I can join if I asked.	.48	.09
IS5. To take the time to review and challenge the present scientific theory I have learned.	.73	.08
IS6. To have the necessary space to work with others to solve scientific problems.	.80	.07
IS7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).	,79	.06
IS8. To test science knowledge through discussions, assignments, or any other class activity.	.64	.08

Table I-16. Factor loadings and standard errors of factor loadings for identification as a scientist—nontraditional learning methods in PHY 2048

Items	Factor loading	S.E.
IS1. To use more than one of my senses to understand present scientific theory.	.66	.06
IS2. To have adequate time to journal or write down what I have learned.	.64	.06
IS3. To hear or read about what today's scientists are practicing.	.74	.06
IS4. To access science experts who have projects that I can join if I asked.	.88	.05
IS5. To take the time to review and challenge the present scientific theory I have learned.	.80	.05
IS6. To have the necessary space to work with others to solve scientific problems.	.79	.05
IS7. To formally present scientific findings to my instructor and/or my peers (such as through a presentation, a blog, or a publication).	.85	.05
IS8. To test science knowledge through discussions, assignments, or any other class activity.	.62	.06

APPENDIX J
COMPARISON OF THEMES RELATED TO STUDENT PERSISTENCE DETERMINANTS AMONG VARYING PERFORMANCE GROUPS IN PHY 2048 AND CHM 2046

Table J-1. Comparison of themes related to student motivation

PHY 2048	CHM 2046
High-performing: (a) Good performance in a course supports sense of professionalism for students, and (b) earning good grades keeps students on career path. Average-performing: (a) In-class clicker questions draw students with important content information, and (b) same as (b) with high-performing. Low-performing: (a) Invested time and money root students in a course (e.g., purchase of Study Edge©), (b) in-class clicker questions as easy points make passing course more attainable, and (c) personal understanding drives motivation.	High-performing: (a) Attraction to the subject makes course appealing, and (b) the role of the instructor can be to foster an interest in the course. Average-performing: (a) Combination of career goals and course requirements prevent students from dropping course, and (b) the attainability of passing keeps students in course. Similar to the theme with the high-performing group, (c) the role of the instructor can encourage students to perform well in the course. Low-performing: (a) The sense of accomplishment influences students to continue in a course. Similar to the theme emerging from the other groups, (b) the “end goal” of being a professional encourages students to remain in courses, and (c) the course being required by an academic track motivates students to pass the course.

Table J-2. Comparison of themes related to student confidence

PHY 2048	CHM 2046
High-performing: (a) External research experiences contribute to sense of confidence, and (b) inability to problem solve on one's own lessens confidence. Average-performing: (a) Specific topics being covered can lessen or strengthen confidence, and (b) Study Edge© empowers students to solve problems but possibly not problems similar to the ones on the PHY 2048 exam. Low-performing: (a) Exam grades provide reference point to how much students should be confident, and (b) confidence results from trial and error of BL affordances.	High-performing: (a) Confident students metacognitively consider strengths and weaknesses as exemplified in their exam responses, and (b) grades reinforce confidence in a course. Average-performing: (a) Exam grades may not indicate student confidence, (b) students exhibit confidence when they can identify what BL affordances help them to learn, (c) the use of BL affordances may need to be re-evaluated to bolster student confidence, and same as (b) with high-performing. Low-performing: Same as (b) in average-performing

Table J-3. Comparison of themes related to science learning

PHY 2048	CHM 2046	PHY 2048
Science learning	High-performing: (a) Learning physics is rewarding due to real-world applications, (b) downfall of real-world application of physics problems is there are numerous, different problems, and (c) applications that illustrate problem-solving like Chegg© encourage science learning. Average-performing: (a) Either the science or mathematical aspects of physics encourage or discourage science learning, and (b) visualizing concepts can be a challenge to science learning, (c) designated times to talk through problems can assist science learning (e.g., discussions related to in-class clicker questions), and (d) the stress of testing diminishes the enjoyment of learning physics. Low-performing: (a) A combination of BL affordances are required to scaffold new students from reading a problem to solving one, and (b) an appreciation for physics does not mean that one will do well in the course.	High-performing: Students are unsure how to identify learning practices to change after they follow prescribed uses of BL affordances. Average-performing: (a) Instructor lecturing methods should be explained for more student participation, and (b) not all students know how to purposefully use BL affordances for learning. Low-performing: (a) The BL affordances involving more instructor contact support struggling students, (b) BL affordances encouraging group interactions can also support struggling students, and (c) BL affordances may mitigate confusion among students yet not be used to their full potential.

Table J-4. Comparison of themes related to identification as a scientist

PHY 2048	CHM 2046	PHY 2048
Identification as a scientist	High-performing: High-performing students felt being a scientist demanded more experiences with and applications of the physics content. Average-performing: (a) Average-performing students felt being a scientist was a future activity that included more initiative on their part and experiences like an internship or more advanced physics classes, and (b) being a scientist demands a “keep-going” attitude. Low-performing: (a) Low-performing students felt far from being a scientist, and (b) being a scientist demands that students understand basic concepts first.	High-performing: Students do not connect learning about science to being a scientist. Average-performing: (a) Perception of being a scientist can vary among the sciences, and (b) a course’s lab experiences facilitate student learning rather than the work of a scientist. Low-performing: (a) Being a scientist and thinking like one are two different things, and similar to a theme from the average-performing group, (b) lab experiences encourage students to apply their knowledge as scientists would.

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BIOGRAPHICAL SKETCH

Brenda Lee Ruei-Chi Such (née Brenda Ruei-Chi Lee) earned a Ph.D. in Curriculum and Education and a minor in Research and Evaluation Methods from the College of Education at the University of Florida in December 2017. Such has presented at conferences held by AECT, FERA, the Online Learning Consortium, and The Qualitative Report, and has published in *Administrative Issues Journal*, *The Qualitative Report*, and *TechTrends.*

Such earned a master's in English Education from the University of Florida in August 2008. In December 2003, also from the University of Florida, Such graduated *summa cum laude* with a bachelor's degree in journalism with a focus on magazine writing from the College of Journalism and *cum laude* with a bachelor's degree in political science with a certificate in international relations from the College of Liberal Arts and Sciences.

Professionally, in the field of instructional design, Such has been an instructional designer and a team leader for the UF Center for Online Innovation and Production. Before her career at the University of Florida, she was an instructional designer for a start-up company focused on providing virtual simulations for nursing education. As an educator, Such was an adjunct from 2016 to 2017 for an undergraduate-level course preparing teachers in training how to create ESOL curriculum and assessment. She was the instructor of record from 2012 to 2015 for an undergraduate-level course introducing students to educational technology. From 2008 to 2010 Such taught middle school language arts and reading.