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Student Learning Behaviors In A Biology Gateway Course: A Mixed Methods Examination Of An Adaptive Courseware Environment

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STUDENT LEARNING BEHAVIORS IN A BIOLOGY GATEWAY COURSE: A MIXED METHODS EXAMINATION OF AN ADAPTIVE COURSEWARE ENVIRONMENT

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Dedication

I would like to dedicate this work to my children, Josiah and Carrie. Your support and belief in me kept me going when nothing else did.

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by

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Abstract

The purpose of this study was to explore how student behaviors, while using an adaptive courseware system, influenced performance in a gateway biology course. This study used a mixed methods approach. Quantitative data was collected from the course's learning management system (LMS) and the adaptive courseware. This data was analyzed using correlations between several metrics, including student course average, exam scores, total time spent using the adaptive courseware, the number of times the participants accessed both LMS content and adaptive courseware content, and the average score of activities and assessments within the adaptive courseware. The quantitative data included semi-structured interviews with 21 participants and follow-up interviews with five of the original 21 participants. This data was analyzed using process, descriptive, and in vivo coding.

This study conducted seven different correlations. There was no significant correlation within three of the seven, including the correlations between the time participants spent on adaptive courseware activities and their final grade in the course, $r_s = .260$, $p = .058$; the participants' access of content through the adaptive courseware content during this time and their final grade, $r_s = -.015$, $p = .912$; and the participants' confidence level with the adaptive courseware content during this time and their score on Exam 4, $r_s = .122$, $p = .379$. There were statistically significant correlations with four of the seven, including those between the participants' access of content through the LMS during this time and their final grade, $r_s = .531$, $p < .001$; the number of LMS content hits during the data collection window and their score on Exam 4, $r_s = .347$, $p = .008$; the amount of time participants spent on the adaptive courseware during this time and their score on Exam 4, $r_s = .298$, $p = .028$ and the amount of time

participants spent on the adaptive courseware during this time and their total score on adaptive courseware assignments, $r_s = .398$, $p = .004$.

Within the qualitative data, three themes were identified, including student perception, relevance, and location. Each of these was furthered divided into three subthemes. Student perception included ease of use, restrictiveness, and participants' comparisons of themselves to others. Relevance included navigating the system, prioritizing usefulness, and reaching goals. Location included using resources, creating space for themselves, and viewing themselves as learners.

This study concluded that the participants interacted with the adaptive courseware using a combination of perception and relevance in order to locate themselves within a comprehensive learning environment (CLE). The CLE is composed of the learner; the LMS and the adaptive courseware, including the content and the technology; and the teacher, with the complex behaviors these interactions entail. The participants' performance, determined by final course average and scores on specific assignments, was not always indicative of their interactions within the CLE. However, their learning behaviors within the CLE did inform their performance.

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Chapter 1: Introduction

1.1 Overview

From works such as Skinner's (2003) groundbreaking *The Technology of Teaching*, educators and researchers alike have been interested in the link between technology and education. Although some theorists have justifiably decried aspects of educational technology (Watters, 2014), the link between the two has been generally viewed as positive. This interest has been manifested in a variety of modalities and delivery methods, ranging from television to filmstrips to audio recordings (Ferster, 2014). While the different technologies and delivery systems have resulted in varying levels of success, educational technology has remained of vital interest to theorists, researchers, and educational practitioners alike.

Researchers have examined various aspects of e-learning. Some of these include the effectiveness of different delivery modalities (Terras et al., 2012; Todd et al., 2017); and student and faculty perceptions of the modalities (Badri et al., 2016; Chiasson et al., 2015; Crawley et al., 2009; Glass, 2017; Wright, 2017). Various aspects of implementing e-learning programs have also been examined, including program leadership (Beaudoin, 2016; Diamond, 2008), program design, (Chipere, 2017; King & Boyatt, 2015), and program implementation (Bosch et al., 2015; Romanenko & Nikitina, 2015). Researchers have also focused on pedagogy and learning in e-learning (Baggaley & James, 2016; Lai, 2015; Li, 2008; Shearer et al., 2015).

Within the larger context of e-learning, there is ample research about adaptive courseware. This research has emphasized such topics as types of adaptive courseware (VanLehn, 2011); the impact of adaptive courseware (Brusilovsky et al., 1998; Truong, 2016); and specific adaptive tools and systems (Hsieh et al., 2013; Koedinger & Aleven, 2007). As a central component of adaptive courseware, learning styles (Claxton & Murrell, 1987; Swanson,

1995) and multiple intelligences (Gardner, 2011; White, 2008) have also received research attention.

This brief overview of e-learning and adaptive courseware research demonstrates that researchers have taken various approaches in their examination of instructional delivery modalities. Important facets of all of this research are the learner, the teacher, and the content. To examine these components, the didactical triangle has been used in education research (Brousseau & Balacheff, 2002). In this framework, the connections between the three different entities - teacher, learner, content - are the construct in which learning takes place. Although the didactical triangle is generally used within mathematics education contexts (Goodchild & Sriraman, 2012), it is useful in this paper's case because it provides a concise visual of the connection between the three components.

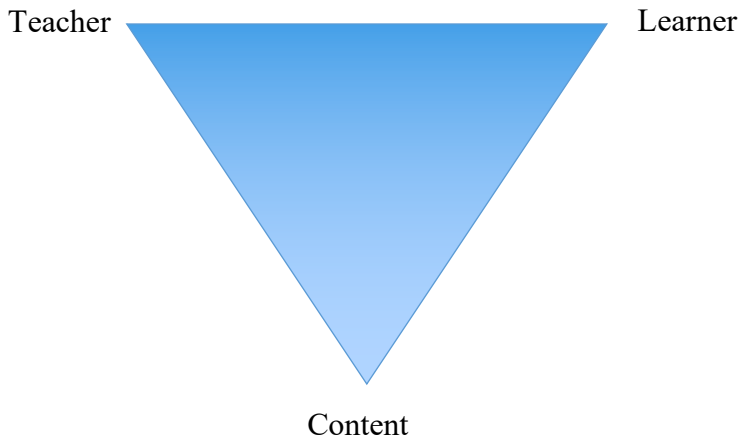

Figure 1.1. Didactical Triangle

While the didactical triangle has effectively demonstrated the relationship between the different nodes within a learning environment, educators have sought a method to illustrate these relationships with the added dimension of technology (Tchoshanov, 2013). One such solution, as seen in Figure 1.2, is Ruthven's (2012) didactical tetrahedron.

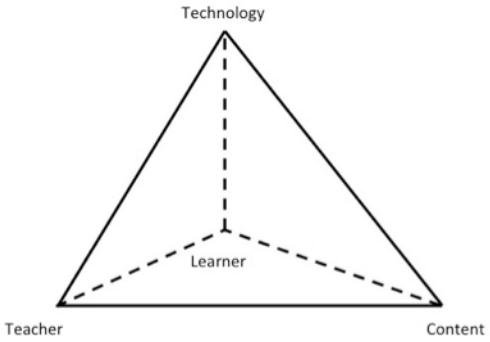

Figure 1.2. Didactical Tetrahedron

This construction is useful as it demonstrates the relationship between all of the separate nodes, and each face forms its own didactical triangle. This study will use it to demonstrate the relationships between teacher, student, content, and technology, which are the critical variables for effective teaching. While this construct echoes Mashaw's (2012) model that he developed to measure an online course's effectiveness, which utilizes the context of the learning, the instructor, the student, the technology, interpersonal relations, and the various advantages and disadvantages of the modality, this research study uses it differently. In this study, the four nodes of the didactical tetrahedron are the focal point of the analysis as complexity theory is utilized to examine how these nodes interact to create a synergy where the knowledge created is greater than the sum of the parts. While the instructor, the student, and the content are obvious, for this study, the technology dimension refers to the adaptive courseware and the learning management system (LMS) used for the biology course. The technology, including CogBooks and Blackboard, is not an intervention, as in this case, the technology constitutes the environment in which the learning takes place.

This didactical tetrahedron model is analogously related to the Technological Pedagogical Content Knowledge (TPACK) paradigm. Some researchers argue that TPACK is what teachers must know to adequately teach their students. Shulman's (2013) Pedagogical

Content Knowledge (PCK) construct is the root of TPACK. The TPACK model was proposed by Mishra and Koehler (2006) and includes knowledge about pedagogy, information and communications technology (ICT), content, context, and learners. The TPACK model has been applied to many content areas, most notably computer science (Angeli, et al., 2016), where those authors argue that teachers preparing to teach computer science must have specific knowledge relating to computational thinking. TPACK is mentioned here because it provides an alternative to the didactical tetrahedron to demonstrate that there are options in depicting the connections between the various aspects of learning. This paper uses the didactical tetrahedron because it emphasizes the student, while TPACK is concerned with student learning as it relies on teacher knowledge.

The theory of transactional distance (TTD) has a theoretical background in Moore's (1989, 1991) work on distance education, and is concerned with four variables: dialogue, structure, autonomy, and transactional distance. "Transactional distance is a psychological variable that modulates in relation" (Saba & Shearer, 2018, p. 1) with the other three, where "these constructs are measured by the quality and quantity of communication between the instructor and the learner" (p. 1). Within the specific domain of adaptive learning, this theory provides a framework for researchers to emphasize individual learners within larger educational systems, such as adaptive courseware and LMS. This focus on individual learner needs is, of course, a central feature of adaptive courseware, as will soon be demonstrated. Although transactional distance is not a specific focus of this study, a focus on communication between learner and instructor is a key component of this study. TTD focuses on individual performance in educational settings, rather than aggregating student performance data. This is in response to the common result among much instructional technology research, where "no statistically

significant difference" (Saba & Shearer, 2018, p10) is found between treatment and non-treatment groups, which these authors argue is the result of individual outcomes being obfuscated in the data aggregation process (Saba & Shearer, 2018).

1.2 Statement of the Problem

The primary problem this study addresses is poor student performance in gateway courses, leading to retention problems at the university as a whole. Gateway courses are those courses that are prerequisites for students to take more advanced courses related to the same content or to progress in a given program of study. Gateway courses have been identified as a key barrier to student retention (Bloemer et al., 2017). Student academic preparedness, as well as organizational and social support, have been identified as factors attributing to academic success in all types of college courses. This is in keeping with finding that high school Grade Point Average (GPA) and American College Testing (ACT) scores have been identified as the primary indicator of gateway course success in algebra and English composition (Jenkins & Butler, 2013). Other factors, such as peer tutoring, have also been identified as having positive effects on performance (Dvorak & Tucker, 2017). Many core area gateway courses have DFW rates, the percentage of students who receive a D or an F, or withdraw from the course, that approach 50%. This would mean that in an introductory biology course with an enrollment of 130 students, as many as 65 of them would be unable to move forward within their chosen degree program. Given the importance of gateway biology courses for retention in many university science programs, identifying factors affecting student success in these programs represents a salient problem for researchers.

The integration of adaptive courseware within gateway courses addresses other problems as well. Adaptive courseware provides the students with a self-directed pathway through the

content that is based upon their performance in previous sections of the course and their learning styles, as well as timely and pertinent feedback. This can help students navigate the course with more support than would be normally provided in a traditional course not using adaptive courseware. Although adaptive courseware can be viewed as an intervention, in the case of this study, the adaptive courseware is a component of the complex system that comprises the environment in which the students are learning. More specifically, the adaptive courseware is one type of resource available in the classes that the participants had access to along with instructor-provided resources.

1.3 Purpose

The purpose of this study is to address a gap that exists in the research regarding adaptive courseware in biology gateway courses. There is some research exploring adaptive courseware's effectiveness on instruction (Yarnall et al., 2016), but there is little research examining how adaptive courseware influences the interactions between students, teachers, content, and technology. The interactions between these four nodes are central to learning and instruction, and within an instructional environment that utilizes adaptive courseware, the interactions become more complex than in a traditional non-adaptive environment.

1.4 Research Questions

The primary research question for this project is: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting?

This question was designed to help explore the relationships between the learner, content, instructor, and technology, in relation to student learning as indicated through student

performance. In order to explore this question more deeply, three sub-questions have been developed:

1. How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments?
2. How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection?
3. How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection?

1.5 CONTENT OF THE STUDY

This study took place in the biology department at a large public university situated along the United States and Mexican border. The university had an enrollment of approximately 21,000 undergraduates at the time of the study. This study was part of a larger grant from the Association of Public and Land-grant Universities (APLU) for implementing adaptive courseware into gateway courses in order to improve DFW rates. This program, the Adaptive Courseware for Early Success (ACES) initiative "centers around the use of adaptive courseware to improve student success outcomes to eliminate the equity gap for low-income students, students of color, and first-generation students" (Association of Public and Land-Grant Universities, n.d.). The Personalized Learning Consortium team from the APLU assisted the university to become an active member of their networked community related to adaptive courseware solutions nationally. The APLU facilitated the adoption of technology (information, research and contacts), recommending processes for course design/redesign and best practices for using dashboard functions in adaptive courseware with specific interventions with students.

1.6 Role of Biology Gateway Courses

At the university where the study was conducted, Biology 1305, general biology, is a gateway course, because students need to pass it in order to progress to more advanced biology courses. Biology 1305 plays an important part in several programs of study. Not only is it a prerequisite for all upper division biology courses, it is a required course for the following degree plans: Bachelor of Arts (BA) in biology, Bachelor of Science (BS) in biochemistry, BS in biological sciences, BS in cell and molecular biochemistry, BS in environmental science with a concentration in environmental biology. It is also a course option for the following degree programs: BA in chemistry, BA in geological sciences, BS in chemistry, and BS in geological sciences.

1.7 Significance

This study is significant for two reasons. First, it provides a glimpse into a previously unexplored dimension of adaptive courseware in gateway biology courses. As previously stated, gateway courses are perceived as the gatekeepers of academic programs. As such, they have been the focus of reform efforts (Berg & Hanson, 2017; Brookins & Swafford, 2017; Rife & Conner, 2017). While previous research has emphasized the effectiveness of adaptive programs (Yarnall et al., 2016), this research examines how student interactions with the adaptive courseware correlated to student performance. This study is significant because it examines how participant behaviors within the courseware itself affected student performance.

Second, it exposes new avenues for research in adaptive courseware, particularly in how it can be used to revolutionize teaching and learning. In K-12 education, there is a model used "for selecting, using, and evaluating technology" (Hamilton et al., 2016, p. 434) called SAMR, which stands for Substitution, Augmentation, Modification, and Redefinition. Developed by

Puentedura (2013), this model serves as a useful metric to describe the significance of this study. According to Puentedura (2013), the highest level, redefinition, can be described as the state where technology "allows for the creation of new tasks, previously inconceivable" (Puentedura, 2013, p. 2). While this project did not use this model in its strictest conception, it is useful to help conceptualize how adaptive courseware can change student learning.

1.8 THEORETICAL FRAMEWORK

Constructivism is the educational approach that emphasizes that students create meaning for themselves. That is the conceptual framework of this study. This study relies on two major conceptualizations of constructivism. The first is Vygotsky's socio-cultural view of constructivism, where learning drives development (Moll, 2005). The second is Bruner's (2003) model of learning as an active process, where the learner builds learning on previous concepts. The focus of this study is not on how the adaptive courseware facilitated conceptual change. Rather the focus is how the students' interactions with themselves, each other, the instructor, and the content facilitated learning.

To provide focus to this conceptual framework, this project uses complexity theory as the theoretical framework. Succinctly defined by Morrison (2008) as "a theory of change, evolution, adaptation, and development for survival" (p. 365), which "breaks with simple successionist cause-and-effect models, linear predictability, and a reductionist approach to understanding phenomena" (p. 365), complexity theory possesses a long evolutionary tale. This evolution began in mathematics research after World War 2, through computer science developments during the 50s and 60s, to the study of complex adaptive systems (CAS) beginning in the 80s (Alhadeff-Jones, 2008).

Complexity has been utilized within education research before. Kuhn (2018) makes a

compelling case for using complexity theory in education, beginning with her assertion that "Ideas from complexity science have been utilized and developed by a great many people working in what may broadly be described as social rather than scientific domains" (p. 283). According to Kuhn, "complexity and education may be brought together because in the language of complexity, such human cultural settings, productions and institutions as educational endeavor are complex and dynamic" (Kuhn, 2018, p. 2907). While Kuhn (2018) does point out that there are criticisms of using complexity theory in educational settings, because "it draws on images and metaphors from mathematics and science" (p. 2916) and social sciences have "equivalent or superior means of addressing similar ideas" (p. 2916), she asserts these objections can be overcome. She maintains that these objections reflect overly delimited, static epistemological and ontological viewpoints.

Complexity theory has already had a strong influence on educational research. Semetsky (2008) makes the connection between complexity theory and Dewey's pragmatism, arguing that it is responsible for inspiring "a logic of education and learning that would incorporate novelty and creativity, these artistic elements being part and parcel of the science of complexity" (p. 83), a connection that Mason (2008a) argues that other educational researchers have found compelling. Radford (2008) has also made a connection between complexity theory and an important constructivist, in this case Bruner, as he argued that scaffolding is inherently complex in its application of connections between old and new concepts. In an analysis of complexity and school reform, McQuillan (2008), while admitting that she is using it metaphorically*y* rather than strictly scientifically, argued that this theory provides an excellent theory for examining the complex whole, the institution, stakeholders, policies, and other constituent aspects, of any school reform. This study did not use this framework metaphorically like McQuillan nor strictly

scientifically. Rather, it was used as a framework to examine the complex interactions between the nodes on the didactical tetrahedron—between the students and the courseware, between the students and the faculty as mediated by the courseware, and within the courseware itself, to explore the complex interactions between these disparate entities as the students create meaning from the content generating synergy within the system.

In an examination of educational philosophy and complexity theory, Morrison (2008) emphasized connectedness and emergence. In schools, this connectedness is evidenced through the fact that "children are linked to families, teachers, peers, societies and groups; teachers are linked to other teachers, support agencies (e.g., psychological and social services), policy-making bodies, funding bodies, the state legislature, and so on" (p. 21). In this study, many of the connections are beyond the bounds of the classroom, for example the APLU, the university's education goals and policies, and the developer of the adaptive courseware itself. Although these connections are behind the scenes and not the focus of this study, the connection between these entities and the students themselves that create a more complex environment should be acknowledged in a study focusing solely on the students and the courseware. For Morrison (2008), emergence "is the partner of *self-organization"* (p. 22), in other words, the ability of a complex system to have organization emerge from chaos. While the courseware in this study is undoubtedly organized already, this paper argues that the educational environment in this study, including the student, the faculty, the content, the courseware, and other unseen elements, create an unorganized *whole* in which self-organization emerges in order for the students to create meaning for themselves. This assertion is supported by Mason's (2009) position that "trying to isolate the influence of a particular factor either in explaining failure or in effecting change" (p. 122) is futile. As will be demonstrated in chapter three, the connections between the nodes of the

didactical tetrahedron made possible with the adaptive courseware and the students' academic performance in the course will be quantitatively examined. These connections will be analyzed through a convergent exploration of both qualitative and quantitative data in order to examine the complexity between the nodes.

While complexity theory is "not a single unified set of ideas" (Cochran-Smith et al., 2014, p. 106), the various forms of the theory emphasize "wholes, relationships, open systems, and environments" (p. 105). This study utilizes complexity theory because it can be used to provide an ontology that can bridge the differences in qualitative and quantitative research, through emphasizing interactions, irregularity, unpredictability, and emergence (Haggis, 2008). As Haggis (2008) argues, "a complexity ontology provides a way of thinking about institutions, cultures, groups and individuals which are in some important ways, always unique" (p. 169).

Complexity theorists have identified varied characteristics inherent in complex systems. Mason (2008b) provides us with a comprehensive list gleaned from some of the major researchers of the theory. While this study emphasized those characteristics that are components of dyads that will be seen later, the reader will be able to see most of these traits running throughout the existing literature. Mason's (2008b) list includes the following 12 characteristics, though some features have been combined for the sake of clarity. Internal diversity is the different characteristics of the entities that create the system. Internal redundancy is the commonalities between system entities that benefit the operation of the system. Neighbor interactions are the connections between the various nodes that combine to create the system. Decentralization of control does not refer to an educational free-for-all. Rather, this dimension refers to the dispersion of control of interpretations and meaning making. Randomness refers to those elements that compel the elements of the system to modify their actions and interactions.

Coherences are those occurrences that require the system to preserve itself. Positive and negative feedback loops are those loops that encourage or discourage certain actions within the system. The flow and preservation of information refers to the course and maintenance of information that helps the system survive. Stability is the ability of a system to maintain its integrity in the face of obstacles or threats. Reproductive instability the ability of the system to create anomalies. Connections are those robust interactions between nodes in the system. Scale refers to the fact that the system must be sufficiently large to create and maintain complexity.

This study emphasized Davis and Sumara's (2014) grouping of six of the 12 previously discussed dimensions. For Davis and Sumara (2014), there are three dyads that demonstrate the true nature of a complex system—specialization, trans-level learning, and enabling constraints. These three dyads are essential concepts throughout this study. Specialization includes internal diversity and internal redundancy and is the characteristic of a complex system where the various facets of the system are both sufficiently similar to each other and sufficiently different from each other to ensure continued existence of the system (Davis & Sumara, 2014). Comprised of neighbor interactions and decentralization of control, trans-level learning allows the various nodes within a system to learn from each other because there is no centralized source of all learning (Davis & Sumara, 2014). Enabling constraints describes the ability of the system to "balance randomness and coherence" (p. 135). Enabling constraints are of particular interest to those working with complex systems. While there is some disagreement when examining particular examples, in general, there is agreement that enabling constraints limit the activities of a given system in such a way that the system creates something that would have been impossible to create otherwise (Davis, 2008; Snowden, 2016). Davis and Sumara (2014) argue that this organization emphasizes the lack of equilibrium in emergent systems.

These three dyads, specialization, trans-level learning, and enabling constraints, are composed of the six dimensions of a complex system—internal diversity, internal redundancy, neighbor interactions, decentralization of control, randomness, and coherence, respectively—that best describe the complex relationships between learner, instructor, content, and technology identified in this study.

1.9 Summary of the Methodology

This study uses the QUAN → QUAL convergent method (Creswell & Plano Clark, 2018). Convergent "design is used when the researcher wants to compare quantitative statistical results with qualitative findings for a complete understanding of the research problem" (Creswell & Plano Clark, 2018, p. 68). Generally, the quantitative and qualitative data is collected concurrently but separately, with both types of data having "equal importance for addressing the study's research questions" (Creswell & Plano Clark, 2018, p. 69). A section of Biology 1305 that was using adaptive courseware as part of the APLU grant was the focus. The quantitative data included adaptive courseware data and LMS data from all of the students enrolled in the chosen section who agreed to participate.

The qualitative portion of the study was composed of participants who were enrolled in the chosen section of Biology 1305 that was using the adaptive courseware. This portion consisted of both initial and follow-up interviews. The initial interviews included 21 participants, taking approximately one hour to complete. The follow-up interviews, lasting about 15 minutes each, were conducted with five of the original 21 participants.

1.10 Limitations

There were limitations within both the quantitative and qualitative portions of this study. For the quantitative portion, the primary limitations included the following:

- The study examined a single introductory college level biology course
- The semester-long time frame complicated the process of collecting the data after informed consent had been received
- The adaptive courseware and the LMS had issues with data specificity—meaning that there were limits to the amount of student performance and behavior data available from the LMS and adaptive courseware. These systems also provided data that did not contribute to the purpose of the study.
- The data only included those students who were still in the course at the time of data collection and provided informed consent, thereby not reflecting how students who dropped the course or did not consent to participate were interacting with the system

1.11 Definition of Terms

As with many other research areas, defining terms is not as straightforward for this topic as one might think. To begin, a definition of online learning is required. Tomei (2010) defines it as "a web-based approach to education in which students access online resources and communicate with instructors and other students through computer-mediated communication" (166). This definition provides us with the necessary components of learning related to the term, including the student, the content, the instructor, and the technology. This definition is not without some caveat, though. Singh and Thurman's (2019) literature analysis examined the evolution of the term online learning and its synonyms since 1988, finding that there has been some persistent confusion regarding definitions. While there has been a clear evolutionary path regarding choice of term to describe learning through technology delivered via the Internet, since 2017 there has been a strong tendency to use the terms e-learning and online education. For this study, the terms e-learning and online education are used interchangeably, and in place of older

terms, such as web-based education, computer-assisted learning, and e-tutoring (Singh & Thurman, 2019), unless the older term was necessary to preserve the intention of the original research.

While there are numerous terms related to online education pertinent to this study, the definitions of the most common will be provided here. Any specialized terms that arise during the course of this study not defined here are defined within context. To begin, a definition of these terms—blended learning, face-to-face instruction, hybrid course, learning management system, adaptive learning, and adaptive courseware is sufficient.

While online learning describes the education modality in which instruction is delivered through the Internet, face-to-face (FTF) instruction describes the delivery modality at the other end of the spectrum that has "a student attend a physical class at a predetermined day and time" (Tomei, 2010, p. 96), requiring direct interaction with the instructor to learn the content.

With the modalities at both ends of the spectrum defined, the next two important terms are blended learning and hybrid courses, both of which entail some sort of mixture of the two previous modalities. Blended learning, or blended course, is often used as a synonym for the term hybrid course (Simonson & Seepersaud, 2018), referring to "a combination of online and face-to-face methods" (p. 71). Some researchers have further delineated between the two by arguing that blended courses require "a majority of their instruction in a face-to-face environment but have a portion of their class online" (Archambault & Crippen, 2009, p. 365). This paper uses the term blended learning to avoid the connotations that the term hybrid learning has acquired.

Learning management system (LMS) is a much more straightforward term to define. According to Tomei (2010), an LMS is "a web-based application that delivers and manages

training content," (p. 141), including discussion forums, exams, videos, and multimedia presentations. The university where this study was conducted uses Blackboard as its LMS, and it is the delivery method for the adaptive courseware.

Adaptive learning is central to this study. It is important to differentiate this term from adaptive courseware. An unintentional conflation of these terms could certainly lead to a misunderstanding of this study's central arguments and conclusions. Adaptive learning, at the most basic level, refers to the process of modifying a student learning environment in alignment to their individual background knowledge and learning needs. For this study, the guidelines adopted by the University of Central Florida (UCF) used to categorize a course as adaptive or not include some vital features of this construct. To be considered an adaptive learning course at UCF, the course, "regardless of platform" (Cavanagh et al., 2020, p. 174) must be "objective-based" (p. 174), contain "personalized content and assessments" (p. 174), provide "an adaptive learning pathway" (p. 174) that adjusts to students' needs, and optionally can contain a variety of course materials in various media, or provide "questions and content using variables and conditions" (p. 174).

The term adaptive courseware is essential to this study, because it is the central focal point. Typically, adaptive courseware is defined as that technology that delivers content and instruction in a method optimized for a given learner. The adaptation is often based on student learning styles. For this study, that definition is too broad. As it stands, that could refer to almost any instructional technology. Therefore, this study defines adaptive courseware as that technology that provides content using the instructional format most effective for a given student—particularly by affording students pathways through instruction designed to meet learning needs. The term adaptive learning system is used frequently in the literature and will

feature prominently in the literature review. For this study, the term adaptive courseware is used in lieu of adaptive learning system for the sake of conciseness and clarity.

1.12 Researcher Positionality

I have been a full-time k-12 educator for over 20 years. I have also taught part-time at the local community college concurrent to this experience since 2003. I have never taught science, except for computer science at the high school level. However, I do have extensive experience with educational technology, through my roles as a classroom teacher, high school librarian, and instructional technologist. I have no ties to the university other than my role as a PhD student, and no connection to the biology department other than this study. In the quantitative portion of the study, I had no direct contact with the participants, except when I emailed them to ask for their participation in the qualitative portion of the study. For the qualitative portion of the study, I had contact with them during the interviews, as well as through email when needed to contact them with follow-up questions or for clarification.

1.13 Researcher Reflexivity

Although I have no experience teaching science, I do have strong connections with educational technology, having an MS in library science and an MS in information systems. I have designed online instruction for a variety of applications, including professional development for high school teachers and librarians, information literacy skills courses for high school students, history courses for high school dual credit students, and classes for students in a computer science magnet program. I have experience in a number of learning management systems, ranging from when I hosted my own Moodle server in my garage in the early 2000s, through WebCT, to Blackboard and Schoology. Given this extensive background in educational technology, it is clear that I have a demonstrated faith in the effectiveness of online education.

This background had two effects on this research project. First, it provided me with a thorough understanding of the multiple components of e-learning, including infrastructure requirements, system operation, course design, and course evaluation. Second, being aware of the bias I have toward e-learning's effectiveness helped me contextualize my findings.

Chapter 2: Literature Review

This literature review will focus on delivery modalities and their related themes, adaptive courseware, multiple intelligences (MI) and learning styles (LS), along with gateway courses. While the research in these sections relies on a variety of theoretical frameworks, as each of these themes is examined, there will be a concentrated effort to point out how complexity theory is able to provide a theoretical lens that can focus on the issues identified within the research.

2.1 Overview

While this study specifically focuses on college students' experience with adaptive courseware in a biology gateway course, the review of the research for this study requires the examination of several disparate elements. First, various themes related to delivery modalities are explored to contextualize the study within the larger framework of online education. Given the number of themes, this review is organized around four fundamental questions, which will in turn address the central topics related to the study's guiding questions.

a. How do students and professors view the different modalities?
b. How are distance programs developed, led, and delivered?
c. How best do students learn in a given delivery modality (i.e., FTF, online, hybrid)?
d. How successful are distance programs?

Within the answers to each of these questions, there are multiple subthemes, ranging from issues of student-student relationships to concerns of cost effectiveness. By organizing these far-ranging themes as the answers of the preceding four questions, this review will build a cohesive view of the current state of research regarding delivery modalities. This portion of the literature review is organized along the four previously mentioned questions, subdividing the relevant issues within each. While much of the research is cross disciplinary in nature, there are

those studies that focused entirely on students within a given subject, when relevant to the overall purpose of this literature review, they will be pointed out. As shall be demonstrated, however, often research goes beyond these categories, drawing conclusions that could potentially have an impact across disciplinary boundaries. This cross-disciplinary aspect of the research makes complexity theory an ideal framework for analysis because it is well suited at examining systems that branch across multiple discourses (Horn, 2008; Mason, 2009).

Second, the topic of adaptive courseware is explored, as the review's focus continues to sharpen as it approaches the research gap. In this section, various topics are examined, including intelligent tutoring systems, learning styles and adaptive courseware, types of adaptive tools and methods, and finally, specific adaptive systems. This section of the review is designed to provide the reader with a focused assessment of the current research regarding adaptive courseware, which is the primary focus of this study. However, as it follows the previous exploration of electronic learning, this section of the review is more fully situated within the larger environment for the reader.

Third, the review delves into the literature regarding multiple intelligences (MI) and learning styles (LS). Although this may seem like a divergent path, a brief investigation into this topic is necessary because of adaptive courseware's reliance on these constructs. While the adaptive courseware utilized by the course during this study did not rely on MI or LS, this section has been included because these constructs are present in the literature regarding other adaptive courseware systems. This section will provide a brief overview of both MI and LS, a discussion of their backgrounds, and current criticism of both.

Fourth, the review will examine the literature regarding gateway courses, the environment of the current study. This section will begin with an overview of the research, segue

into the importance of gateway courses on student retention, and finish with a review of current efforts to improve gateway courses.

2.2 VIEWING MODALITIES

2.2.1 Teacher Perceptions

How teachers or students perceive an educational theory or technology is obviously an important factor in its success or failure. Some researchers have explored instructor perceptions of delivery modalities, finding that perception is often reality. Crawley et al. (2009) examined one instructor's attitudes toward migrating from FTF to online, finding that the instructor discovered that the online environment was more effective than originally expected. Chiasson et al. (2015) also investigated instructor perceptions within the context of migrating instruction from one delivery system to another, concluding that instructors did not have to make an expected pedagogical shift from FTF to online. In this study, the instructors utilized a synchronous online model, rather than the more popular asynchronous approach.

2.2.1.1 Perceptions of Teaching Online

Obviously enough, teacher attitudes toward a given modality affect that faculty member's perceptions. Glass (2017) found that how well the instructor was able to make the content significant for students and how well the instructors performed their role online were significant factors for positive teacher attitudes about online education. In their study of an online doctoral program, Roumell and Bolliger (2017) found that, while teachers expressed the need for additional support from their given university, they still thought that they were able to provide meaningful communication opportunities to their students. Later, this study's findings will demonstrate that teacher-student communication forms the cornerstone of the relationship that

makes the online educational experience successful. Again, this is an example of the interaction between nodes on the didactical tetrahedron, specifically the teacher and the learner.

2.2.1.2 Challenges of Teaching Online

There are a variety of challenges inherent in online teaching. In his examination of faculty perceptions of institutional-level barriers to online education, Neben (2014) identified practical concerns such as pedagogy, time constraints, and faculty workloads. Indeed, when thinking about online teaching, one of the first things that comes to mind to many people is the technological aspects of this environment. While technological expertise is a natural element of this type of instruction, there are more challenges than those facing online teachers. In their cross-national study of success factors in online learning environments, Barberà et al. (2016) argued that teachers put a larger emphasis on "content, social presence, instruction and their interactions than about technological matters" (p. 25). Although they focused on K-12 teachers, Archambault and Crippen (2009) found that online teachers face their own particular set of challenges, including being more creative than in FTF instruction and adapting their pedagogy and classroom management strategies for online courses.

While Glass (2017) found that some teachers felt creatively empowered when teaching online, others expressed feelings of isolation that they did not experience when teaching FTF. Institutional support is another concern for online faculty, in their examination of online doctoral supervisors, Roumell and Bolliger (2017), found that these supervisors were unsatisfied with the support they received from their institutions. While these faculty members were convinced that their institution valued the work being done, they believed that they received "little institutional support in learning how to become a supervisor" (Roumell & Bolliger, 2017, p. 86) in an online environment. The lack of this type of support is related to the next issue with faculty

challenges—professional development.

2.2.1.3 Professional Development

Institutional support is essential to positive faculty perceptions and experiences with e-learning. In their article, Brown and Ramasamy (2015) found that faculty transitioning to e-learning experience concerns at different levels, including awareness, informational, personal, management, consequence, collaboration, and refocusing. A common denominator when addressing these concerns is professional development (Brown & Ramasamy, 2015). Researchers have examined various aspects of professional development, including its links to course quality (Baran & Correia, 2014; deNoyelles et al., 2017).

It may initially appear to be an easy fix, simply providing more professional development opportunities to faculty to increase course quality. In their case study examining leadership, however, Richardson et al. (2015) found that professional development was one of the larger problems facing institutional leadership, because of the dearth of effective online instructional models for teachers and geographic obstacles. A central component of the difficulties inherent to professional development for e-learning is the complexity of interactions that it entails. Professional development cannot solely focus on the faculty. Baran and Correia (2014) argued that educators must "recognize successful online teaching in higher education as an outcome of the interaction of supports at three different levels: teaching, community, and organization" (p. 98). As we have seen earlier, this interaction is an essential aspect of complexity theory.

Even when focusing solely on faculty, professional development opportunities offer a host of complexities. In their study, Bawane & Spector (2009) examined a variety of proposed constructs for professional development. They examined a number of models, finding professional development focuses on a number of roles that faculty must inhabit. In their

research, they found that professional development models include a variety of categories, most of which include a combination of management, technological, pedagogical, and administrative skills. They also examined the variety of roles that online instructors must inhabit, including professional, pedagogical, social, evaluator, administrator, technologist, advisor, and researcher (Bawane & Spector, 2009). This variety of roles and developmental models demonstrates the complex nature of online education, requiring a variety of skills to address the myriad interactions between the student, the content, the instructor, and the technology.

As the literature will shortly address, presence is an essential element of successful online instruction. Duncan and Barnett (2009) examined the importance of pre-service preparation in online instruction. A core element they identified was presence—social presence, cognitive presence, and teaching presence (Duncan & Barnett, 2009). For their study, they relied upon a Vygotskian interpretation of social constructivism, so their identification of presence as a key component of online instruction is understandable. Given the need for social interaction for the student to create meaning, the various actors must be present, or there will be no interaction, thereby, no meaning making. Just a casual examination of the types of presence required—social, cognitive, and teaching—demonstrates the complex nature of any given online instructional event.

2.2.2 Student Perceptions

As identified in the section discussing teacher perceptions, student perceptions of online instruction is a vital component of the learning experience. While various aspects of this topic will be explored elsewhere in this literature review, this section includes three areas of interest direction related to student perception. First, perception is a primary component of the decision-making process as students are determining in which modality to take a given course as also

evidenced in this study's data. Second, student perception of effectiveness is a key component of actual success. Finally, student perception is vital to their learning experiences, because it influences how they view the technology, the content, and the instructor. While an exhaustive exploration of student perception is beyond the scope of this paper, this section will demonstrate that student perceptions add to the complex nature of this system, particularly when considering the dyads of complexity, which are the focus of this study, including specialization, trans-level learning, and enabling constraints (Davis & Sumara, 2014).

2.2.2.1 Choosing a Modality

While research focused on teacher perceptions has been presented, most current work emphasizes students. Student perception is important because researchers have found that, in order to design effective instruction for both FTF and online modalities, instructors must understand student perceptions (Wright, 2017). A good starting point from the student point of view is how perceptions influence student decisions toward a given modality. Tichavsky et al. (2015) have explored why students chose the delivery methods that they did in the first place, finding again that student perceptions are vitally important in these decision-making processes. Tichavsky et al. (2015) found that most students will choose FTF classes over online or blended, but this choice is most likely based on stereotypes of what online classes are like rather than first-hand experience with that modality. Badri et al. (2016) found that student perceptions about ease of use of online educational environments and usefulness influenced student decisions about taking an online course. Robinson (2017) explored how universities can use student perceptions to influence their acceptance of online courses, finding that universities need to leverage positive student experiences within online courses to help influence other students to choose the same modality. This is a tacit acknowledgement that student perceptions often override actual

experience when choosing modalities, and is a concrete example of enabling constraints—in that it demonstrates the balance between oppositional forces in student decision-making processes.

2.2.2.2 Perceived Effectiveness of Modalities

Once the decision about which modality with which to engage has been made by the student, the next step is to explore student perceptions about the modality. Several studies have examined how students perceive online and FTF instruction. In their study of business students, Fish and Snodgrass (2015) found that both graduate and undergraduate students preferred FTF instruction. Other studies have not found such cut and dried results, however. Jahng (2004) found that while there was "no significant difference in student achievement" (p. 64) between the modalities, online students did not exhibit the levels of satisfaction with the course that FTF students did. In their study, Carver and Kosloski (2015) examined student perceptions toward key success factors between FTF and online instruction. In this study the participants favored online instruction for the domains of active learning and autonomy. In this instance, autonomy relates to trans-level learning (Davis & Sumara, 2014), where students interact with the various nodes of the didactical tetrahedron in accordance with immediate needs, free of centralized control. However, in the important domains that include relationships and collaboration, representing the student node of the didactical tetrahedron, the students preferred FTF. These two domains are examples of trans-level learning, also. This indicates that within a complex educational system, these dyads are present regardless of modality. In their study of student preferences, Carver and Kosloski (2015) found that students had positive perceptions of online instruction, finding it an effective replacement for FTF instruction. Although these findings differ from Carver and Kosloski's (2015), they are also indicative of trans-level learning.

Researchers have also explored how socioeconomic, gender, and ethnicity factors influence student perceptions. These factors are indicative of the dyad of specialization. Specialization is the balance between diversity and redundancy. In their interactions with the different modalities, students exhibit enough differences between each other to ensure the creation of a robust system while also remaining similar in that they are all students. Horvat et al. (2013) found that gender has no effect on students' perceptions of satisfaction in a distance learning environment. Hostager (2014) found that online resources could balance any effects from gender. While blended learning supposedly provides the benefits of both modalities, while mitigating their shortcomings, researchers have also examined student perceptions of this modality. Dziuban et al. (2018) have explored blended learning, finding that students, regardless of minority status, had positive perceptions of blended learning in relation to access to instruction and how the modality ultimately lead to student success.

2.2.2.3 Student Perceptions of Learning

Other researchers have, like Lin and Tsai (2011), examined student perceptions of instruction delivery and learning, examining how students' perceptions impacted student thinking. This echoes Davis and Sumara's (2014) construct of specialization that illustrates the diversity of systems. Lin and Tsai (2011) studied how student perceptions of learning management was influenced by the delivery system, finding that web-based instruction might increase higher order thinking. Sobhy and Megeid (2014) found that it was the quality of instruction more so than the delivery method that influenced students' perceptions about course satisfaction, reaffirming what others have found (Ganesh et al., 2015) that the instructors' practice most influenced student perceptions regarding course effectiveness. Agdas et al. (2014) similarly concluded that the simplicity of the course and instructor communication were vital

components for a positive student perception. López-Gavira and Ometeso (2013) found that a student's country of origin was a strong predictor of her perception of the efficacy of an online course, another example of specialization. While the validity and reliability issues with the Myers-Briggs Type Indicator (MBTI) have been long documented, Boghikian-Whitby and Mortagy (2016) utilized that framework to explore student perceptions of modality preference. In this longitudinal study, the authors found that there was no long-lasting relationship between MBTI type and modality preference (Boghikian-Whitby & Mortagy, 2016).

While this review will explicitly examine learning later, this section will briefly explore how it relates to student perceptions. Horzum et al. (2015) took an interesting approach, exploring how students perceive their own learning through the relationship between their learning and how ready they were for online instruction coupled with their motivations. The authors found that students' reasons for pursuing higher education and how well they believed themselves prepared for the challenges of online instruction affected their perceptions of their learning.

Instructional tools are an obvious part of learning. For online students, it has been found that perceptions of usefulness directly affect how worthwhile the students found the tool (Florenthal, 2016). While this might appear overly circuitous at first glance, and painfully obvious with a second, Florenthal (2016) added an important dimension to the scholarship by acknowledging the relationship between perception and reality. This is similar to Ellis and Bliuc's (2016) findings in their study that a student's approach to inquiry affects his perception of his learning. Ellis and Bliuc (2016) found that a more profound inquiry approach led to more profound learning.

Alongside instruction, important components of any course are engagement, trust, and communication. Martin and Bolliger (2018) found that icebreakers and collaboration were key components toward building engagement in a given course, fostering positive student perceptions. Wang (2014) concluded that student perceptions of trust within an online educational environment were built best by instructional factors rather than issues such as privacy protection. In regards to communication, Hajibayova (2017) found that proper use of communication tools, such as online forums, was vital for positive student perceptions, provided that there was a strong teacher presence. This is an example of Davis and Sumara's (2014) trans-level learning, because these forums allow for the decentralization of learning. Hawkins et al. (2013) similarly found that teacher-student interactions affected student perceptions of a given course, though this study took place in a high school environment, unlike the other research included here.

2..3 Distance Program Logistics

2.3.1 Finances and Institutes of Higher Education

This section answers the question: How are distance programs, developed, led, and delivered? This question encompasses several themes, including leadership at different institutional levels, student services, financial issues, and program design. Given the current fiscal realities of many higher education institutions, economics is a likely starting place. While it has been taken as a matter of fact that online instruction is a ready method for saving money, primarily due to lower over-head costs, research has found that the financial realities of online programs are quite complex (Bramble & Panda, 2008). However, the general assumption that online education leads to savings is evident in non-empirical literature. Luskin and Hirsen (2009) argue that students reap the benefits of reduced costs from distance education. Poulin and Straut

(2018) have examined perceptions about financial realities, finding that while institutional leaders believe that online education will save money, faculty believes that online instruction is actually more expensive. In his analysis of education financial research, Rumble (2012) developed an exceedingly thorough exploration of financial models for both FTF and online instruction. His analysis found that differences between the two modalities in relation to scalability, fixed and variable costs, material costs, and teacher-student ratios does equate to different financial models between the two. The myriad issues related to finances demonstrate the dyad of enabling constraints in that institutions are attempting to address the single issue of finances, but subsequently exposing other concerns in the process.

2.3.2 The Role of Student Services

Related to finances are student services, which includes those services provided to students that support their pursuit of higher education, such as disability services, student orientation, and information centers. These services do represent a considerable portion of institutional budgets. While there is a common belief that fewer students on campus require fewer services, Bailey and Brown (2016) argued that this is not true. More online offerings require different types of student services, not fewer of them, because of the reliance on technology. While there are still opportunities for additional research in this topic, it is clear that the relationship between online education and lower costs is not as clear-cut as many believe.

2.3.3 Leadership Levels and Models

Within any program implementation, leadership is a vital factor for success, and implementing a modality change is certainly no exception. Chang and Lee (2013) found that "both leadership style and conflict management mode have a strong influence on learning performance" (p. 986)—clearly demonstrating leadership's importance. Beaudoin (2016)

identified key leadership themes for distance education, finding that there are good and bad programs, that leaders can thwart programs through their lack of vision, and that more leaders are becoming convinced that online education is as effective as FTF programs. These themes are indicative of both trans-level learning and enabling constraints (Davis & Sumara, 2014), in that they represent the diversity, redundancy, randomness, and coherence inherent in many leadership processes. Diamond (2008) argued that educational leaders still need to determine online education's ability to change pedagogy and improve practice, as well as these programs replication, scalability, effectiveness, and longevity. These issues are still of primary concern for educational leaders.

The impetus for such a change is a hot topic among institutional leaders. While some researchers have called into question the economic and instructional benefits of online education, Soderstrom et al. (2012) nevertheless argued that increasing online educational offerings could lead to economies of scale and better working conditions. Given that this article was targeting educational leaders, it is interesting to note that these leaders are still being exposed to ideas that have not been definitively proven through empirical research.

However, there is still research that backs up the implementation of online programs. Beaudoin (2015) argued, "the lesson for higher education is that it cannot thrive by relying on its hegemony and legacy as the exclusive purveyor of information and ideas, delivered in traditional formats and means" (p. 34). Regardless of whether or not online education offers all the benefits that have been promised, the fact is that institutions have to respond to changing climates. This is an example of specialization (Davis & Sumara, 2014), where the institution has to offer courses in a variety of modalities. Amirault (2012) studied key issues about institutional reasons for transitioning to online programs. While this article was somewhat overly positive, the author did

make some credible and timely points. Amirault (2012) argued that reduced funding from state and national sources is leading the charge for increased offerings. More importantly, however, is the assertion that it is not only technological change that is prompting more online education, but that it is the students themselves who are clamoring for more online programs (Amirault, 2012). This seems to indicate that regardless of the institutional realities concerning infrastructure, faculty preparedness, fiscal issues, and services, the primary motivator should be student expectations, given that universities should be student-driven, a prime example of the decentralization of control (Davis & Sumara, 2014).

Once the decision for implementation is made, the next issue is how to commence the implementation process. Wickersham and McElhany (2010) argued that leaders must have positive attitudes toward quality standards to implement effective programs. "Standards can provide a starting point for quality design and, coupled with the ongoing technology support provided by the administration" (p. 11), can mitigate resistance toward the implementation of these programs. While this does emphasize standards, the role of leadership in implementing these standards and ensuring adherence to them is obviously vital.

The question becomes then: what is an effective leader and what is her role in implementing an online program? There has been research emphasizing the differences between traditional higher education leaders and leaders within virtual environments. While most university leadership would still be considered traditional, increased online programs will lead to increasing calls for virtual leaders. Kuscu and Arslan (2016) argued that the virtual leader has to establish motivation and confidence because this new environment is a "freer, harder-to-follow environment where organizational loyalty level is more variable" (p. 153).

This is similar to transformational leadership, a leadership paradigm that emphasizes motivation and change management. Gallego-Arrufat et al. (2015) argued that within online distributed leadership, "the transformational leader influences the groups motivation and organization" (p. 95). This indicates that leadership at this level must emphasize the personal aspects of the stakeholders, and not rely solely on the management of infrastructure, services, and instruction. This does not mean, however, that leaders can ignore these other aspects of education. Keppell et al. (2010) argued that "distributive leadership has transformed teaching and learning . . . By focusing on redesigning subjects and courses, fellows have engaged in innovative and relevant research" (p. 18) that has transformed pedagogy.

2.3.4 Program Design

Program design encompasses several important subthemes, such as instructional design, access, program design, and course design. This section includes research on information and communications technology (ICT) also considering its integral relation to program and course design.

Instructional design is the foundation of a successful online course. The choice to adopt an online program is an obvious place to start our examination. King and Boyatt (2015) argued that there are three primary factors that affect program implementation at universities. These factors include the IT infrastructure, faculty abilities and mindsets, and student perceptions. These factors are examples of Davis and Sumara's (2014) construct of specialization, in that they exhibit the diversity of entities and the necessary redundancy of information systems. Interesting enough, these identified factors do not include financial issues as a separate consideration; rather they focus on infrastructure, which is necessary for effective delivery, and personal traits and characteristics of the two primary stakeholders involved in the daily operations of the course.

Rogers-Shaw et al. (2018) argued that Universal Design for Learning (UDL) provided a model for effective instruction that emphasized access and instruction. They argued that increased distance learning offerings led to an increasingly diverse student body, which in turn led to the need for a structured instructional design model that emphasized diversity and learning. Chipere (2017) explored the necessary ingredients for an online program, finding that utilizing a design framework, which emphasized cost, e-learning, and students led to a successful, sustainable program. This demonstrates that a design framework can help create the balance between randomness and coherence, i.e., enabling constraints (Davis & Sumara, 2014). A model or framework is probably a worthwhile tool, given that some programs have had difficulty becoming successful. Smith et al. (2016) explored the difficulties instructors had in switching modalities from an FTF to online instruction, even though as instructors, they had considerable experience with both the content and FTF pedagogy.

According to Warner and Hewett, (2017) effective course design, including of instructional materials, is vital for a successful online course. They argue that instructors must be capable of producing effective instructional materials so that they become more empowered and aware of their role in the course design process. This is predicated upon a substantial obligation from teachers. Getting teachers to volunteer to teach an online course, with the inherent time commitment for the development of materials, is a difficult process in most colleges. Cook, Ley, Crawford, and Warner (2009) argue there are five internal motivating factors that faculty demonstrate—including "1. Ability to reach new audiences that could not attend classes on campus; 2. Opportunity to develop new ideas; 3. Personal motivation to use technology; 4. Intellectual challenge; and 5. Overall job satisfaction" (p. 152). These motivating factors demonstrate the complexity in creating online educational resources, effectively including

elements of each of the dyads, specialization, trans-level learning, and enabling constraints (Davis & Sumara, 2014).

They also identified five obstacles—including "1. Lack of technical support provided by the institution; 2. Concern about faculty workload; 3. Lack of release time; 4. Lack of grants for materials/expenses; and 5. Concern about quality of courses" (Cook et al., p. 152). As we saw earlier with the motivating factors, these obstacles also exhibit elements of each of the three dyads (Davis & Sumara, 2014). These findings have been echoed by Peerani (2013), who identified several of the same factors, including money, training, and a perceived absence of relationships between students and teachers. As has been explained, the last two are vital components of the didactical tetrahedron. These factors must be leverage in order to ensure that teachers have the opportunity and ability to identify and create effective online instructional materials.

Incorporating ICT issues into the design of programs and courses is an obvious concern. If a student is unable to access the instructional material or they experience lag during the completion of online activities, then this will obviously impact student achievement, learning, and satisfaction. Basahel and Basahel (2018) argued that ICT is so important that it can actually mitigate issues, such as leadership, students and faculty with inadequate technology skills, poor services, problems related to diverse populations, communication difficulties, and ineffective instructional materials, among others. While the authors argued about the efficacy of their particular system to fix the aforementioned problems, they made good points about how ICT can ameliorate or even eliminate these problems. While it is difficult to argue that any general type of ICT or specific information system (IS) is a panacea for institutional shortcomings, the

efficacious implementation of ICT can overcome some limitations that institutions and individual stakeholders have.

2.3.5 Implementation of Programs

An integral part of any distance program is the technology used, either within the infrastructure, the interface, or the instructional material itself, although as the role of technology increases, so does the instructor's role (Romanenko & Nikitina, 2015). As American youth have become increasingly dependent on their mobile devices, education delivered through these devices has become more prevalent. Joo et al. (2016) examined mobile technology and education, finding that the students found the devices useful in relation to how much they thought the device would be user friendly.

The primary technology being utilized in higher education is LMS, generally referred to as virtual learning environments (VLE) in Europe and Asia. These systems are vital in providing opportunities for trans-level learning, one of the key dyads of complex systems identified by Davis and Sumara (2014). Mundkur and Ellickson (2012) found that most students had a positive experience with these technologies. In their study regarding technology choices, Bosch et al. (2015) make an argument that should be considered by anyone weighing the implementation of any ICT technology. While ICT's role is obvious, relying on technology for technology's sake, ignoring the fact that the problems the technology is supposed to fix should be the focus of any ICT implementation is a grave mistake (Bosch et al., 2015).

Xu et al. (2014) examined virtual learning environments (VLEs) and their role in meeting diverse student learning needs. They used an experimental design, finding that this "learner-centric" (Xu et al., 2014, p. 431) approach based on a constructivist framework led to "agent-based VLEs" (p. 436) that "can serve as powerful tools that dynamically personalize online

instruction to meet learner's preferences, learning pace, goals, and desires" (p. 436). This decentralized approach to instruction is indicative of trans-level learning. Su et al. (2018) found that teachers reported "higher scores of teaching self-efficacy" (p. 2749) while using ITSs. Self-efficacy "derives from the social cognitive theory" (Su et al., 2018, p. 2756).

Program logistics are essential to distance learning success at institutions of higher education. Decisions at the higher levels of these institutions will echo throughout the program at every level. As demonstrated, some programs make these assumptions that are not verified with empirical data. Ranging the gambit from finances, services, leadership, design, to implementation, a misstep with any of these facets can adversely affect an otherwise well-planned program.

2.4 Student Learning

How do students learn best in a given modality is the question that this section of the review addresses. Of all questions examined in this lit review, this one contains the broadest themes. This category includes research regarding learning and pedagogy obviously, but also includes research related to student and faculty relationships, online presence, and various types of communities, all of which are important facets of student learning as components of the didactical tetrahedron. For example, Alzahrani (2015) found that interactivity between the student and other students, the teacher, the content, and the system improve learning in e-courses.

2.4.1 Learning and Pedagogy

This section addresses learning and pedagogy, since those two themes are central to the guiding question of this study. Although some authors have questioned whether online learning is living up to its potential regarding learning (Shearer et al., 2015), this study will assume that at

least some students are able to learn through this modality. Li (2008) found that creating an online community that fosters learning is possible, going so far to argue that some students reported building relationships that would not be possible to build in an FTF environment, possibly because of trans-level learning, and the decentralization of control (Davis & Sumara, 2014).

Intrinsic factors for student learning are important targets of researchers. Although intrinsic factors, such as motivation and self-efficacy are sometimes viewed as static and part of a given mindset (Dweck, 2016), Chyr et el. (2017) found that a blended learning environment could actually develop these characteristics. Zorn-Arnold and Conaway (2016) found that intrinsic motivational factors, including how eager a given student is to learn, is indicative of how well the student will ultimately learn in an online environment. In their study of students in an online course, Hu and Gramling (2009) found that students who were able to utilize Self Regulated Learning (SRL) strategies, including metacognitive tools such as goal setting, planning, and active reading strategies, reported higher rates of learning in an online environment. Although these strategies are also utilized in FTF environments, some of the students reported using strategies limited to an online course, such as repeatedly accessing available audio files (Hu & Gramling, 2009). This demonstrates that instructors must utilize a variety of instructional tools.

Similarly, Lai (2015) found that students were exhibiting high levels of learning through participation in online discussion modules. While discussions have been an integral part of instruction since the Socratic method, the asynchronous nature of online discussions allows students to reap the benefits of this strategy without the temporal and spatial limitations of the earlier method. This strategy is a prime example of trans-level learning. While these forums are

planned and implemented by the instructor, they embody decentralized control because the student has ample control over how to post, when to post, and to whom to respond. However, Li (2008) reported less favorable results in a study about online discussions, finding that students turned in posts that just met the minimum requirements just before the deadline.

Other researchers have examined the course's role in learning, as well. Li et al. (2017) found that the leading factor related to student learning, as reported by the students themselves, was how well the learning modules met the students perceived needs. These modules represent both the content and technology nodes of the didactical tetrahedron. Another important factor related to the learning modules was the advice students received when completing the modules. Chen and Bennett (2012) found that students reported relying solely on online readings and discussions unfavorably, thinking that this type of instruction in an online course lacked the intellectual clout that the same activities carried in an FTF course. Although the authors were not focused on a formal learning environment, Baggaley and James (2016) found that lack of facility with online technology and resources inhibited learning. Lawton et al. (2012) explored the relationship between formative assessment and distance learning, finding that prompt feedback did lead to increased learning.

2.4.2 Student and Faculty Pedagogical Relationships

Although the instructor has equal importance with the other nodes on the didactical tetrahedron, the specific pedagogical role should be emphasized. Several researchers have examined this relationship in regard to online education. Bawane and Spector (2009) found that instructors felt that pedagogical concerns as they adapted to an online environment were among the most important issues identified. The challenges that instructors face in adapting their pedagogy to a new modality are a ripe area for exploration. Serdyukov (2015) found that e-

pedagogy requires increased levels of collaboration with stakeholders throughout the institution, including content, pedagogy, and technology experts. Lewis and Wang (2015) found that instructors were both pleasantly and negatively surprised in their initial exposure to online educational technologies. The instructors discovered that the technologies were more effective, while simultaneously requiring more time, than they had assumed. While many participants reported problems with the LMS itself, they were "surprised by the level of interaction that took place during the online assignment discussions" (Lewis & Wang, 2015, p. 116). This interaction provided by the system's online forum feature allowed a depth of relationship with their students that they did not expect. This demonstrates how trans-level learning can be enhanced through e-learning because the various features allow for both centralized and decentralized learning. Although researchers have identified various problems that faculty face as they adapt their pedagogy, Gregory and Salmon (2013) found that professional development that emphasizes flexibility and context could overcome many of these issues.

Hinted at throughout this review, the importance of relationships and community is integrally important to how students learn, so this review will examine the bulk of this research here. Presence, as defined as the instructor and students being involved in the online activities; being readily available through electronic communication means, both synchronous and asynchronous; and being attentive to the social dynamics at work in the online course, is central to building community and forging relationships in an online environment. Creating presence in an online learning environment is challenging given the nature of the learning environment (Terblanché, 2015). However, the benefits do appear to be worth the struggle. Presence has been positively correlated to building motivation among online students through proactive and positive emails from the instructor to the student (Robb & Sutton, 2014).

2.4.3 Presence and Community Building

Social presence, defined by Short et al. (1976) as "the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships" (p. 65), has long been identified as an important component of online learning (Cobb, 2009). Presence is a key component of building relationships, and relationships are central to learning and student success, as we have seen through both the didactical tetrahedron and Davis and Sumara's (2014) dyads. Positive relationships and support combined are a leading indicator for student learning (Lundberg & Sheridan, 2015). While two specific types of communities will be examined separately, communities of inquiry (CoI) and communities of practice (CoP), building communities in general is a core component of relationship building. While there has been some question about whether or not a true community can be built online, Murdock and Williams (2011) found that students in an online course had similar perceptions of what a community entailed for students, concluding that online communities are possible. While Sentas et al. (2018) found that students could learn empathy, a key facet of a healthy relationship, Hylton (2007) found that students were more engaged in online activities when facilitated by an instructor than by another student. This indicates that there are parameters for successful community building, which require additional research.

CoI and CoP are related terms, and reasonably popular constructs with which to explore online education communities. Developed from the work by Garrison et al. (2001) that focused on the importance of social, cognitive, and teaching presence in online communication in education. CoI can be defined as those communities created through the desire to research a given problem, such as collaborative learning efforts in an online course. Developed from Lave and Wenger (2005) CoP includes those communities created by individuals who are in a similar

profession or position, for example, a group of computer scientists developing a new algorithm. Although these are radically simplified definitions of these quite complex concepts, they are sufficient for our purposes—examining how these two specific types of communities have been utilized in online education research.

Oyarzun and Morrison (2013) analyzed current literature on CoI and cooperative learning, attempting to ascertain the effect this type of community had on student learning. They found forming a CoI did not affect learning. Given that CoP focuses on types of practitioners, this seems an ideal framework to examine online education, given that online education includes many such families, including faculty, developers, students, IT professionals, etc. It also seems like an ideal situation in which to find trans-level learning, in that these types of communities do not have a central locus of control. Correia and Davis (2008) explored the intersectionality of these communities, finding that collaboration between these existing CoPs allowed stakeholders to maintain a view of the big picture, including conflict management and shifts in group dynamics across the institution. Golden (2016) also explored the benefits of CoP, particularly for faculty, finding that the communication and exchange afforded by this type of community can provide vital support for instructors. A CoP can perform roles outside of communication and idea exchange as well. Freeburg (2018) found that online CoP can create knowledge by leveraging experience across the community to create knowledge outside of the traditional curriculum.

2.5 Modality Effectiveness

In regard to effectiveness, several studies (Todd et al., 2017; Terras et al., 2012) found that blended courses, where FTF is augmented by online instruction, were the most effective delivery method. This modality expands the interaction between the nodes of the didactical

tetrahedron because it relies on a mixture of modalities, where the student interacts with the content, the instructor, and the technology in a more complex manner than in a FTF course. Likewise, in their study of student collaboration in both online and FTF environments, Tutty and Klein (2008) found that either method was effective, though it ultimately depended on the structure of the collaboration. Hizer et al. (2017), in their comparison of the efficacy between FTF and online environments within a supplemental instruction situation, argued that both are equally effective when helping undergrads in need of additional instructional support. This is similar to Mashaw's (2012) model that he developed to measure an online course's effectiveness that utilized the context of the learning, the instructor, the student, the technology, interpersonal relations, and the various advantages and disadvantages of the modality. All of this research seems to indicate that it is a complex interplay of factors that creates effective courses.

As presented earlier, Todd et al. (2017) completed a meta-analysis of 66 studies, finding that a hybrid delivery was the most effective method. This finding was corroborated by Rivera's (2016) literature review of empirical studies, which examined online science labs. While the various studies had mixed results, Rivera (2016) concluded that the hybrid modality was the best solution, because it produced the best results as measured by student performance. Other researchers have echoed this claim; Moskal (2017) concluded that hybrid courses have substantial potential for "increasing access to learning while maintaining positive student outcomes and satisfaction" (p. 24). This is not to say that there are no problems with the approach. Westover and Westover (2014) found that in the course they studied that the online load was excessive for the course's purpose and that students were ill-prepared for the FTF portions.

Researchers have examined the relationship between content and technology extensively. For this review, content includes the knowledge within a given course such as the concepts, procedures, and facts related to a given discipline, while the technology includes the modalities themselves and the related tools used within the modality, including discussion forums, e-texts, electronic tests, and various multimedia tools. Both of which are essential components of the didactical tetrahedron.

2.5.1 Technology and Student Success

Inherently, the tools used within a given modality are essential to student success, both perceived and actual. The various technological tools utilized in e-learning allow for trans-level learning by decentralizing most of the student interaction with the content. Although some researchers have argued that more work needs to be done about incorporating social media and online tools into education (Hamilton et al., 2016), there has been some research that has had promising results. Genç and Tinmaz (2016) found that there were gender differences among participants' perceptions of tool effectiveness, with females preferring elements with a strong visual focus. Marjanovic et al. (2016) found that the quality of the delivery system itself, such as a given LMS, affected the systems efficacy, while Horvat et al. (2015) found that regular use of the Moodle LMS led to higher rates of perceived effectiveness and satisfaction with the course among students. This clearly shows that the technology node of the tetrahedron plays as vital a role in student learning as the other three.

When it comes to how effective the tools themselves are, researchers have achieved mixed results. Babcock and Georgiou (2019), in their examination of adaptive courseware, found that it did not improve student learning. In his study of the effectiveness of an e-text in a flipped instruction course (a type of a hybrid modality), Enfield (2016) found that the students in a

JavaScript course thought the e-text and the hands-on activities were very useful in learning the content. It is interesting that even within some research that was ostensibly about teacher or student perceptions of the different delivery systems (Chiasson et al., 2015; Crawley et al., 2009) issues about effectiveness arose. This seems to indicate that this theme will be at least somewhat prevalent in research about instructional delivery models, even when it is not the primary focus.

While these students trusted the effectiveness of their e-texts, other students have not been as successful with their e-tools in electronic environments. Riera et al. (2018) found in their mixed method study of undergraduates that students did not trust the accuracy of the online exams. This is echoed in Whitelock et al. (2015) who found that pedagogy must evolve in response to online instruction so that study time is more effective. Again, this is ample evidence that the four nodes of the didactical tetrahedron are essentially linked; one cannot divorce one from the other. In other words, specialization, trans-level learning, and enabling constraints are at work connecting the various nodes with each other in such a manner that a complex system is created.

2.5.2 Factors Affecting Student Success

There have been a number of factors identified as essential to student success in online instruction, including "institutional commitment to student success, and preparedness" (Hepworth et al., 2018, p. 45), a mixture of communication and participation modes (Menchaca & Bekele, 2008). There have also been factors, including learning style and technology proficiency that have been deemed as nonfactors for success (DeTure, 2003). While a thoroughly comprehensive examination of these factors is beyond this paper, the factors that are of particular relevance to this study will be examined, including those that emphasize the importance of the learner, the instructor, the content, and the technology. This review will further refine its focus

on these four facets to emphasize specialization, trans-level learning, and enabling constraints—the four dyads (Davis & Sumara, 2014) that are the framework for this study's exploration into how complexity theory applies to online instruction.

2.5.2.1 Student and Faculty Interactions

This review has examined research that explored the relationship between the student and the content and the student and the technology, there is also research that has explored the student-student and student-teacher relationships in relation to instructional modalities and effectiveness. The starting point in these interactions is obviously the student, the prime feature in decentralized education. Many researchers have explored the student factors in relation to effectiveness. Goodridge et al. (2017) found that there were no differences between learning styles among students taking a synchronous online course and those taking a FTF course, both being convergent learners. This point seems even more important given that Cheng and Chau (2016) found that a student's learning style was related to increased achievement because it was related to how much the student participated within the course. To further illuminate the importance of the student node within our model, it is interesting that Lee, Choi, and Kim (2013) found that those students lacking metacognition proficiencies and possessing poor self-regulatory skills generally were more likely to drop out of a given online course.

2.5.2.2 Student Readiness

Another factor that has been explored is student readiness. Kaymak and Horzum (2013) examined post-graduate social science and science students, finding that "a positive and significant relationship was found between readiness for online learning and perceived interaction" (p. 1794), with those students who were more ready for online learning having a better perception of the interactions between themselves and the instructors than those students

who were not as ready. This is indicative of the importance of the student-student and student-teacher relationship within educational environments. If a student is not ready for online instruction, then that individual will be unable to form the relationships between the other actors.

Although their study was conducted at a high school, Hawkins et al. (2013) found that increased interaction between students and teachers led to increased graduation rates. This seems to verify the importance in the student-teacher relationship. Lai et al. (2016) affirmed this finding, when they found that students felt that teachers should take a larger role in online educational tools when used outside of the classroom. Oddly enough, this study also found that teachers thought that they should play a smaller role within the use of these tools. This study demonstrates not only the importance of the student-teacher relationship in online learning, but also the disconnect between the two about how this relationship should manifest itself.

This disconnect seems related to Wang's (2014) assertion that a teacher's online instructional practice is more likely to build trust with their students than factors such as privacy tools built into the instructional system itself. This could indicate that the teacher in an online environment, whether totally online or hybrid, has an inordinate amount of power and responsibility when it comes to the creation of the student-teacher relationship. This is a possible example of feedback loops within complex systems (Mason, 2008b), in that the teacher is essential in the creation of situations where behavior is either enforced or corrected through the interaction of the student, content, and technology. Although, as seen in Hajibayova (2017), there is some debate about what actually constitutes teacher presence in an online environment, it is obvious that instructors are as vital within an online learning environment as they are in a traditional FTF course.

2.5.2.3 Course Quality

An issue related to effectiveness is the quality of a given course or program. What quality means in a class can be a bit ambiguous (deNoyelles et al., 2017), but it is basically comparing a course with a set of standards (deNoyelles et al., 2017). While the question of which modality is the most effective is still being researched, there are sufficient findings to suggest that online education leads to increased student success compared to FTF courses (Alkharusi et al., 2010). Therefore, this section of the review will emphasize online education.

The issue of where to focus one's attention when attempting to assess quality is an obvious first step. Zhang and Au Yeung (2003) conducted an early attempt to identify priorities in regards to quality assessment. While they focused on determining the quality of distance programs for purchase, their findings are important because they emphasize the gathering of system and student information, and the ability to organize and access this type of information. These researchers identified five characteristics of effective quality measurement for effective system choice, including culture specificity, diversity issues, creating a database with information regarding each system, allowing students to access their information regarding learning needs, and creating a database of all information gathered from all metrics. These characteristics exemplify specialization, with their focus on diversity, trans-level learning, with their emphasis on interactions; as well as enabling constraints, with their highlighting of organization and coherence.

Given the importance of assessing online programs, the question of metrics arises. Currently, there are several sets of standards for assessing the quality of online education. Two of the most important are the International Association for K-12 Online Learning's (iNACOL) *National Standards for Quality Courses* (Pape et al., 2009), which include the domains of design,

technology, student assessment, and course management. The other popular set of standards is Quality Matters' (2018) *Higher Education Rubric Standards*, which includes quality assessment standards and helpful rubrics for program and course design. There are others, of course, but these are the two most widely used, with the latter being the industry standard.

While Piña and Bohn (2014) have argued that standards focus on course design to the detriment of other instructor issues, the fact that all higher education accreditation agencies rely on standards (Southard & Mooney, 2015) demonstrates the recognition for some type of quality assurance, even if the focus at this time may be a bit one sided. Regardless of whether or not the focus of standards needs to be broader, encompassing more than course design and delivery technologies, some researchers have explored the role of professional development (deNoyelles et al., 2017), at least implicitly recognizing the importance of the instructor's role in quality assurance.

When one has decided to measure quality, the next step is to determine what to measure. There has been research that has tackled many different aspects of online education. While we examined leadership earlier, a brief examination of leadership's role with quality assurance is appropriate here. In their research, Palmer et al. (2013) examined leadership and quality, finding that planning and institutional organization were more important leadership concerns than technology in relation to quality. While technology is related to student satisfaction (Palmer et al., 2013), leadership must take into account all issues related to quality.

One cannot overly belabor the importance of students within the quality assurance process. Researchers have examined several facets of online education as related to students. Taft, Perkowski, and Martin (2011) examined class size and delivery modality in relation to quality. They found that for online education an ideal class size is between 16-40 students. This

indicates that there is an upper limit to course size, regardless of modality. Although an examination of Massive Open Online Courses (MOOC) is outside of the scope of this paper, Taft, Perkowski, and Martin's (2011) findings seem to argue against the efficacy of such an approach and against leadership hopes of creating economies of scale with larger class sizes in order to reduce costs.

2.6 ADAPTIVE COURSEWARE

For this section of the study, the focus is adaptive courseware. Educators are attracted to adaptive courseware because it appears to offer personalized learning at a fraction of the cost that FTF instruction with the same differentiation would entail (Kerr, 2016), an assertion found earlier in Dagger et al. (2005). While there are thematic alignments with the previous sections, adaptive courseware will be analyzed in a separate section to specifically focus on it in one area, since it is the focus of this study. For this review, the following categories—intelligent learning systems, learning styles, adaptive tools, and specific systems—will be the units of analysis.

2.6.1 Adaptive Learning

A key component of adaptive courseware is the concept of adaptive learning as a whole. While adaptive learning is currently a trending topic in educational research, Botsios et al. (2008) have argued that it has been a part of education as embodied in LMSs since the early 2000s. For example, early research examined the role of hypermedia in instruction. Mampadi et al. (2011) found that hypermedia adaptations actually influence perception more than they do student achievement.

The potential benefits of this model are a primary focus of the literature regarding adaptive learning. Johanes and Lagerstrom (2017) examined the possibilities and drawbacks of adaptive learning, finding that it has the potential to provide clear, personalized content in a

timely manner that is optimized for all students, thereby enabling teachers to provide quality instruction, and providing new avenues for educational research (Johanes & Lagerstrom, 2017). The potential drawbacks are that it can provide a limited view of content; endanger student privacy through mismanaged data; focus on a narrow learning dimension, sometimes neglecting social, emotional, or physical aspects; collect data that represents little more than background noise; discriminate against some learners; and become a financial burden to organizations (Johanes & Lagerstrom, 2017). In her examination of adaptive learning, Phelps (2020) examined the difficulties faced when adopting such a model and discussed the potential benefits of the model, including cost reduction, increased access, and increased quality. These difficulties include team dynamics, vendor relationships, timelines, and the identification of appropriate roles for all team members (Phelps, 2020).

Other researchers have examined the difficulties inherent in creating adaptive learning programs in universities. Mirata et al. (2020) found that the organization must be ready to commit to the model as part of its larger mission, be prepared to create the necessary infrastructure, and provide the necessary institutional support. A key component of this institutional support is faculty engagement, the focus of Johnson and Zone's (2018) exploration of the topic, where they found that engaging faculty in the course development process, along with professional development and institutional support were vital factors in mitigating faculty concerns with adopting adaptive learning.

Although there are documented limitations to adaptive learning, Bryant et al. (2013) argued that post-secondary education should adopt adaptive learning because, potentially at least, this model could "produce a higher-quality learning experience (as measured by student

engagement, persistence, and outcomes) at potentially reduced cost by making high-quality instruction more scalable" (Bryant et al., 2013, p. 5).

A key feature of adaptive learning is the flexibility it affords students. Dziuban, Moskal, Johnson, and Evans (2017) found that students of diverse demographic backgrounds at two separate universities "responded positively to the added flexibility" (p. 51) adaptive learning provided, although there were differences in their reported satisfaction with other aspects of the model. In another article examining the differences between two universities that adopted adaptive learning, Dziuban, Moskal, Parker, Campbell, Howlin, and Johnson (2018) found that adaptive learning provides instructional stability across disciplines in "four dimensions—knowledge acquisition, engagement activities, communication, and growth" (p. 7).

2.6.2 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITSs) are those adaptive systems that provide students with the services provided by personal tutors, but in an electronic form (Steenbergen-Hu & Cooper, 2014). In the context of gateway courses, Hickey et al. (2020), found that ITS can be more effective than remedial classes. Not all research is as clear cut, however. VanLehn (2011) reviewed several experiments regarding ITSs, finding that these systems were not appreciably less effective than human tutoring, while acknowledging that their analysis exposed limitations of many of the included studies. Steenbergen-Hu and Cooper (2014) performed a meta-analysis on the ITS effectiveness, which included 39 studies. They also emphasized the cognitive theory basis of ITSs. They concluded that ITSs "have demonstrated their ability to outperform many instructional methods or learning activities . . . although they are not yet as effective as human tutors (Steenbergen-Hu & Cooper, 2014, p. 344).

As mentioned earlier in this paper, feedback loops are an essential part of complex systems. Feedback is also an essential component of ITS. Aravind and Refugio (2019) used learning curve theory to determine the effectiveness of an ITS. The authors found that the tutor was effective in helping students learn vector algebra by providing "instant feedback and need-based, timely hints (Aravind & Refugio, 2019, p. 36). This is obviously an example of feedback loops (Mason, 2008b), where complex systems are regulated through the enforcement of encouraged behaviors and the dissuasion of discouraged behaviors. Copaci and Rusu (2015) used Prensky's digital native construct in a literature analysis to examine how best instructors can design tutoring systems that will engage digital natives. The authors found that participants across studies exhibited "an on-going preference for trained-e-tutors programs" (Copaci & Rusu, 2015, p. 152). Again, this is related to feedback (Mason, 2008b), a key component of complex systems. Crosby and Iding (1997) argued that before ITSs that can respond to student learning styles can be created, a more thorough understanding of the relationship "between learning styles and performance on tutorials" (p. 375) needs to be understood. Therefore, it is clear that educators understand the importance of expert and timely feedback, but are as of yet unsure about how to most effectively incorporate this feature into ITSs to increase student performance.

Research into various adaptive courseware systems has yielded mixed results. Although some researchers have found positive relationships between the use of adaptive courseware and increased student performance (Karaci et al., 2018; Kulik & Fletcher, 2016), others have not found this connection (Gearhart, 2016). Gearhart (2016) found that the LearnSmart online textbook did not demonstrate a significant performance improvement on exams. Other researchers have found mixed results, as well. Karaci et al. (2018) examined ITSs' effect on retention, finding that, while academic achievement increased, retention levels were not

improved. Kulik and Fletcher (2016) reviewed the effectiveness of ITSs in a meta-analysis, finding that most systems are grounded in cognitive theory, and across the 50 studies, ITSs were shown to be "very effective instructional tools" (Kulik & Fletcher, 2016, p. 67) resulting in "improvement in performance [that] was great enough to be considered of substantive importance in 39 or 78%) of the 50 studies" (p. 67).

2.6.3 Learning Styles and Adaptive Courseware

Learning styles are often viewed as a key component of adaptive courseware. This portion of the analysis begins with an examination of the role of learning styles in adaptive courseware. A brief examination of learning styles and Multiple Intelligences (MI) follows this section. In their literature analysis, Nakic et al. (2015) explored the role of individual student differences in adaptive learning. They found that adaptive learning systems are effective when the adaptation is based upon any of the following student characteristics: learning styles, background knowledge, cognitive styles, material preferences, and motivation (Nakic et al., 2015). Walkington (2013) found that student interests were the most important factor around which to provide instructional adaptations.

Akbulut and Cardak (2012) examined research published from 2000 to 2011 that studied adaptive hypermedia systems. They found that most of the systems were based on cognitive theory. They argued that due to the lack of strong experimental studies, the impact of adaptive educational systems on learner outcomes is unclear. Truong (2016) studied learning styles and adaptive courseware by reviewing 51 studies. She found that learning style theory was applied across many aspects of adaptive courseware, including "assessment, educational games and media choices" (Truong, 2016, p. 1191, arguing that "the findings reveal a complex picture of

the research field with promising results and widening applications, yet many open problems" (p. 1191).

In the educational research regarding adaptive courseware, there is considerable discussion of what exactly is meant by learning styles in adaptive courseware. One popular strategy is to examine the role of field dependence and field independence in adaptive courseware. In this case field dependence denotes individuals who use external contextual clues to decode information, while field independence describes those individuals who "rely on an internal frame of reference" (Chen & Macredie, 2002, p. 4) when deciphering information. In this case both of these learning styles can be understood in relation to enabling constraints (Davis & Sumara, 2014) in that these strategies seek to find the balance between randomness and coherence in a given set of information related to a complex system.

In their meta-analysis of research that examines hypermedia systems in education environments, Chen and Macredie (2002) found that Wilkin's Field Dependence model does provide an effective basis for developing learning models that best leverage the then new study of instructional hypermedia. This seems to validate Ford and Chen's (2000) earlier work that determined that field dependence/independence is linked to certain navigational preferences, although there was no link drawn between these preferences and educational achievement.

Afini Normadhi et al. (2019) examined the literature regarding personal traits and adaptive learning. They found that learning style was the most frequently used "personal trait" (Afini Normadhi et al., 2019, p. 180), while the Felder-Silverman model was the most commonly used model. In their literature review, Moos and Azevedo (2009) explored the issue of student computer self-efficacy in Computer-Based Learning Environments (CBLEs), finding that "although this research suggests that computer self-efficacy may be strongly related to learning

outcomes with CBLEs, other research suggests that the relationship between computer self-efficacy and learning outcomes is not stable" (Moos & Azevedo, 2009, p. 588). They also discuss the social cognitive roots of self-efficacy (Moos & Azevedo, 2009). Mandal et al. (2017) studied a model, which would integrate teacher strategies with student learning information. They found that this "tutoring model has been made capable of incorporating teachers' experience . . . to help building better teaching learning [sic] environment(s)" (Mandal et al., 2017, p. 120).

In her literature review about adaptive courseware, Somyürek (2015) found that "inter-operability, open corpus knowledge, usage across a variety of delivery devices, and the design of meta adaptive systems" (p. 221) are the primary challenges that prevent the wider adoption of adaptive learning courseware. These concerns are the very descriptors of a complex system (Davis & Sumara, 2014). Aguilar and Kaijiri (2007) argued that adaptive courseware based on intelligence types can be effective in teaching students computer programming. Aguilar and Kaijiri (2007) examined the creation of an adaptive courseware system "based on a personalization approach, which includes learning styles and intelligence types" (p. 293), for teaching C#. While they did not test the effectiveness of their system, they did admit that "learner's learning styles and intelligence types may change over time" (Aguilar & Kaijiri, 2007, p. 298), a fact that their system is designed to compensate for. Kelly (2008) studied "the Multiple Intelligence based adaptive intelligent educational system, EDUCE," (p. 307) to determine "how the learning environment should change for users with different trait characteristics" (p. 307). She found that adaptive courseware systems that challenge the student so that they do not rely on "the first presented resource" (Kelly, 2008, p. 334) can improve student performance. Özyurt & Özyurt (2015) examined 69 articles about adaptive educational hypermedia (AEH) that use

learning styles as the basis of differentiation, finding that "positive results were obtained in the studies in general" (355). Brusilovsky et al. (1998) did early work on the role that web-based education would have in adaptive courseware. They argued that diverse user backgrounds should be the basis of successful adaptive courseware systems. Again, this is indicative of the need for diversity within a complex system, a central component of specialization (Davis & Sumara, 2014).

2.6.4 Types of Adaptive Tools and Methods

According to Dagger et al. (2005), adaptive instruction is difficult because creating a truly adaptive experience is both complex and time intensive. They argue that the key to being truly effective lies within the activities and teaching strategies (Dagger, et al., 2005). Dolog et al. (2008) argue that new technologies allow for better adaption, thereby mitigating some of the difficulty in creating said systems. For example, in their examination of the Smart Space for Learning™ (SS4L) framework, they found that it provided a usable method for accessing the most relevant materials from a large collection of e-learning sources (Dolog et al., 2008). In a related vein, Germanakos et al. (2009) examined the role of hypermedia navigation tools to meet the needs of heterogeneous users. Both of these studies exhibit trans-level learning because the resources can be accessed according to the specific needs of a given student. Although not related to trans-level learning, other research has exposed other examples of complexity theory in adaptive courseware. Flores et al. (2012) found that formative evaluation must be used with adaptive technologies in order to evaluate the efficacy of a course's design. This serves as an example of feedback, in that these adaptive tools are there to influence subsequent student behaviors.

Karampiperis and Sampson (2005) took a novel approach to adaption. Instead of the traditional approach that generates concepts in a sequence that meets given rules, their approach creates every sequence and then matches the appropriate sequence to a given learner. They found that this approach is an effective adaptation technique (Karampiperis & Sampson, 2005). This approach, while apparently centralized, is an example of trans-level learning because the students interact with the content based upon their individual needs, not through an arbitrary assignment by an instructor.

Researchers have explored a variety of technology tools' roles in adaptive courseware. Kelly (2008) examined presentation tools, finding that adapting these can increase learning among students who do not generally explore learning options. Magoulas et al. (2003) argued that creating tools for adaptive courseware requires both computer and instructional expertise. This emphasizes both the content and technology node of the didactical tetrahedron.

In the context of adaptive courseware, various technologies have been examined. Melucci (2004) examined hyperlink indexing in e-textbooks, finding that this method is an effective manner to retrieve relevant information. Sessink et al. (2007) argue that creating adaptive learning materials is difficult and beyond many teachers' ability, so an effective adaptive courseware system must not have such requisite knowledge requirements. Sun et al. (2007) found that a system that utilizes learning objects, learning styles, and technology is an effective adaptive instructional tool. Baghaei et al. (2007) found that using the Unified Modeling Language (UML) is an effective method in developing effective adaptive courseware. While this is beyond most teachers, representing the technical expertise that other researchers have identified as a problem, the authors did demonstrate that it is effective. The nodes of the

didactical tetrahedron, learner, teacher, content, and technology, are evident in all of this research, because the interconnections between them are essential for learning.

2.6.5 Specific Adaptive Systems

Koedinger and Aleven (2007) argue that adaptive tools must optimize student involvement in such a manner that provides tutorial interventions that inhibit student progress through the over or under provision of help. This is a prime example of trying to provide a system that is dedicated "to balancing randomness and coherence" (Davis & Sumara, 2014, p. 135). Ghadirli and Rastgarpour (2012) argue that their system that integrates learning styles with an expert system is an inexpensive, fast, simple system that improves learning.

There is ample research regarding adaptive courseware that examines the effectiveness of specific systems, including TEL, InterBook, AHA!, and Web F-SMILE. These systems demonstrate a variety of levels of efficacy. Foshee, Elliott, and Atkinson (2016) found that TEL, an adaptive courseware system, was effective in teaching students mathematics. De Bra (2002) examined InterBook and AHA! to determine the use of hypermedia in developing e-textbooks that prohibit students from accessing links to material that is beyond their current ability level. This is an example of a system attempting to balance the inherent decentralized nature of adaptive courseware with student needs. Hsieh et al. (2013) proposed an adaptive system based on fuzzy logic theory that will provide remedial material for individual learners based on learner preferences. Johnson and Sime (1998) argued that GTE is an effective tool for creating an effective adaptive courseware throughout the development process. Jung and Park (2012) argued their system, that maps OWL ontology onto AHA! Domains, allows authors to design adaptive courseware more quickly.

Various researchers have examined specific systems' effectiveness, to various results. In their exploration of Multi-Attribute Utility Theory in conjunction with adaptive learning in a system called Web F-SMILE, an online computer skills program, Kabassi and Virvou (2006) found that MAUT provides the user with the best learning strategy based upon personal needs and skills. This system represents specialization because the courseware must be able to meet the diverse needs of particular students.

Researchers have found other issues with adaptive courseware, utilizing various systems that attempt to mitigate limitations. Melis et al. (2006) examined ActiveMath and its relation to semantic representation, finding that decentralization and interactions in the creation of course content can lead to developmental problems. Researchers have identified other obstacles in the creation of adaptive systems. Queirós et al. (2014) argued that sequencing in adaptive courseware is difficult because of the lack of tools, and Seqins is a simple sequencing tool that streamlines the sequencing process.

The organization of materials is the focus of other researchers. Although Sosnovsky and Brusilovsky (2015) recommended the topic-based adaptive courseware approach based on current research, others have argued for alternative organizational schemes. Zhuge and Li (2006) found that materials can be more effectively used in a modular context in adaptive courseware when they are separated from the traditional concept-centered approach. This is an excellent example of trans-level learning, in that the developers are attempting to weaken the centralized nature of the concept-centered organizational approach. Other researchers have tackled resource organization as well. Ullrich and Melis (2010) examine a courseware generator system that generates a modular system that users found easy to navigate because it is user-centered. Sancho

et al. (2009) examine the NUCLEO framework within adaptive courseware, finding that the tool was effective but more research needs to determine if the effect is because of the system itself.

Tosheva et al. (2017) explored the E-school system, finding that students performed better after using this system. This was a hypermedia-based system, designed to provide instruction based on student needs. Again, this is a prime example of decentralization, where the students' needs determine navigation through the course. Decentralization is evident in other research as well. In their study of OWLearn, a system that combines adaptive courseware tools with a traditional LMS, Tsolis et al. (2011) found that this system provides an effective, collaborative learning system.

Baghaei et al. (2007) used socio-cognitive conflict theory to frame their presentation of "COLLECT-UML, a constraint-based intelligent tutoring system (ITS)" (p. 159), finding this system effective. Walkington (2013) examined an ITS and how it adapted instruction for students based on background. She found that "an interest-based intervention in a K-12 school during the course of regular instruction over an extended period" (Walkington, 2013, p. 942) was effective. Ford and Chen (2000) found that cognitive style, based on the field-dependent/independent paradigm was indicative of "strategic differences in navigation" (p. 281). Foshee, Elliott, and Atkinson (2016) examined the effectiveness of technology enhanced learning (TEL) through the framework of self-efficacy theory within the context of remedial math courses at a university, finding that the combination of teacher instruction and technology adaptation was effective in improving student performance.

Hsieh et al. (2013) examined an e-learning system based on fuzzy logic theory that based learning paths on the problems the students exhibited in the previous lesson, finding that this system did help students acquire programming sufficiency. Koedinger and Aleven (2007)

explored the balance that ITSs must maintain as they withhold or provide assistance to students using the system. In their review of cognitive tutor experiments, they found that there is a very real danger to student learning if a system withholds or provides too much assistance.

Lin et al. (2016) examined an electronic remediation system based on fuzzy logic that determined the remediation level for each student. Again, this is a pertinent example of trans-level learning, because decentralizes the decisions regarding adaptation from the instructor to a complex system of algorithms based on student needs. Using a pre-test/post-test model, they found that this system significantly improved student learning, nor was there a significant difference in progress between higher and lower-achieving students.

Other researchers have taken different approaches in the application of learning styles to adaptive courseware. Mampadi et al. (2011) used cognitive style to design an adaptive learning system, finding "that learners exhibited more positive perceptions towards the AHLS that adapts to individuals' cognitive styles" (p. 1009). This perception is indicative of the importance of feedback, a key component of complex systems we have seen throughout this review. In similar research, Nakic et al. (2015) performed a literature review to find out what "user individual characteristics" are used as a basis of adaption. Somyürek (2015) studied the literature regarding adaptive educational systems, focusing heavily on why these types of systems are still not widely implemented, finding that "their adoption in actual e-learning is not widespread. Challenges involving inter-operability, open corpus knowledge, the usage of various delivery devices, and the design of adaptive systems" (p. 233) are the primary obstacle to implementation. Sancho et al. (2009) found that the adaptive role-playing game they studied in the context of problem-based learning was "perceived by the students to be useful for learning soft and group work skills, and to develop technical knowledge" (p. 122).

2.7 Learning Styles and Multiple Intelligences

The basic idea behind adaptive courseware is the ability to generate content in a manner designed for a particular learner's given predispositions. This may include teaching concepts using various amounts of text, video, audio, interactive activities, or other assignments. These varied activities are designed to meet an individual learner's particular learning needs. Two popular constructs in which to codify these predispositions are multiple intelligences (MI) and learning styles. Although these two concepts are occasionally used interchangeably, they refer to two very different constructs (Dunn et al., 2001; Denig, 2004).

2.7.1 Multiple Intelligences

Although adaptive courseware typically relies on the concept of learning styles, we will briefly examine the primary ideas behind multiple intelligences and the main criticisms of the theory. Doing this will provide us with the necessary background to more fully explore the general goals of adaptive courseware.

2.7.1.1 Background

First proposed by Gardner in 1983, MI argues that "computational capacities" (Gardner & Moran, 2006, p. 227) can be categorized into eight intelligences. For his purposes, "an intelligence is defined as a biopsychological potential to process information that can be activated in a cultural setting to solve problems or create products" (Gardner & Moran, 2006, p. 227). Initially consisting of seven, and currently including nine intelligences—musical-rhythmic, visual-spatial, verbal-linguistic, logical-mathematical, bodily-kinesthetic, interpersonal, intrapersonal, naturalistic, and existential, the goal of the theory is to "expand and reformulate our view of what counts as human intellect . . . to devise more appropriate ways of assessing it and more effective ways of educating it" (Gardner, 2011, p. 4).

2.7.1.2 Criticism

Considering its vast influence on U.S. educational practices, it is no wonder that the theory has generated its fair share of criticism (Klein, 1997; Waterhouse, 2006; White, 2008). Klein (1997) points out that since Gardner first proposed his theory in 1983 "few researchers have systematically evaluated MI theory" (p. 378), although those that have examined it have called for revisions, clarification, elaboration, and in some cases, outright rejection. Klein (1997) argues that MI theory is conceptually, empirically, and pedagogically weak, offering no real benefit to classroom practice.

While Klein (1997) critiqued MI on multiple fronts, Waterhouse (2006) focused her criticism on the lack of empirical research supporting Gardner's theories. While Gardner and Moran (2006) wrote a concise response to Waterhouse's (2006) critique, the problems that she identified do expose the empirical weakness of the theory that so many public schools have embraced as the panacea for their woes. Waterhouse (2006) wrote a response to Gardner and Moran's (2006) assertions that her earlier criticism missed important aspects of their theory and the evidence that backs it up. Although Waterhouse (2006) pointed out several issues with the empirical evidence for MI, the most important is that, when "a new theory, such as MI theory, is generated by the synthesis of existing findings, then that new theory requires empirical validation" (Waterhouse, 2006, p. 249). This is a vital critique because it questions the very basis of many of Gardner, and his proponents', assertions.

In his critique of Gardner, White (2008) utilized a philosophical and historical approach to examine the justification behind Gardner's theory. After acknowledging the influence MI has had worldwide in classrooms, White (2008) first tackled the philosophical underpinnings of MI, arguing that, according to Gardner, to be classified as an intelligence it has to meet prerequisites

and criteria. White (2008) relied on Gardner's definition of "a prerequisite for a theory of multiple intelligences, as a whole, is that it captures a reasonably complete gamut of the kinds of abilities valued by human cultures" (p. 63). Chief among his issues with this definition is the problem with deciding what culture is the arbiter for this definition. According to White (2008), Gardner is not clear enough about what culture gets to make this determination.

The second step in this process is the criteria used to determine what is or is not an intelligence. While White (2008) explored the problems, as he perceived them with Gardner's criteria, they basically boil down to the unscientific nature of the criteria, including problems with the application and selection of these specific criteria. While White examined different aspects of MI than did Waterhouse (2006), they both identified the perceived empirical weakness of MI.

2.7.2 Learning Styles

As discussed earlier, learning styles are often viewed as related to MI. However, it is its own subject. Since learning styles are the basis of adaptive courseware, an exploration of learning style's history, major models, and criticisms is necessary. It is not the intent of this review to be a critique of learning styles, in that it does not take a position on the existence or not of learning styles. It does, however, analyze the major weaknesses of this theory since so many researchers exploring adaptive courseware make tremendous assumptions as to the efficacy of this theory.

2.7.2.1 Background

As early as 1995 researchers were exploring the factors affecting learning styles. Swanson (1995) explored the then contentious point of whether or not there was any cultural influence on students' learning styles. After briefly exploring the history of learning styles,

Swanson (1995) examined the then extant major learning style taxonomies, finding that most models can be categorized along four main lines: personality models, information processing models, social interaction models, and instructional preference models. After reviewing the major literature, Swanson (1995) found that there are differences between groups in preferred learning styles. Most importantly for this study, she examined Claxton and Murrell's (1987) research on learning styles and higher education, arguing that IHEs must provide professional development on learning styles, promote learning style research, provide opportunities for students to learn how to learn, and evaluate new faculty members in relation to their understanding of learning styles and teaching.

Huber and Pewewardy (1990) also examined learning styles research in regard to race and ethnicity, in order to provide better instruction for all students. Starting from the premise that few special populations at the time were being taught with effective strategies targeted to their specific needs, the authors argued that "the research suggests that even beyond race, ethnic group and social class the person's everyday life experiences impact significantly on cognitive development" (Huber & Pewewardy, 1990, p. 6). While the authors did not examine specific strategies or learning style models, their examination of the subject does provide some basis as to the need for instructional differentiation across group lines.

In her analysis of the research, Wilson (1998) provided a thorough exploration of the major learning style models. Taking as her basis seven relevant questions regarding learning styles, she concluded with some brief critical remarks on the topic. Although Wilson (1998) explored seven questions, for this study the two most important questions are— "What are the implications of learning styles-based teaching on diverse cultural groups?" (p. 4) and "Should teachers address the learning style of each individual student or provide a variety of techniques

that address the styles of groups of students?" (p. 4). After admitting that some researchers contend that most of the research is conducted by proponents of the theory, and there is still inadequate research at the time supporting some of the theories claims, Wilson (1998) concluded by stating that teachers must be aware of various teaching methods and employ a wide variety of strategies that match their students' needs. While this is a thorough exploration of learning styles, the author conclusions do not adequately address her guiding questions.

2.7.2.2 Criticism

Hwang and Henson (2002) reviewed the literature regarding Kolb's learning style inventory. Kolb's Experiential Learning Model argues that concrete experience, abstract conceptualization, reflective observation, and active experimentation converge to form a learning cycle (Hwang & Henson, 2002). The relationship between these four determine which learning style the student exhibits: assimilator, converger, accommodator, or diverger. These terms come "from the combination of an individual's ability on abstractness over concreteness (AC-CE) and action over reflection (AE-RO), an individual is assigned to one of four learning styles:(a) Assimilator (AC and RO), (b) Converger (AC and AE), (c) Accommodator (CE and AE), or (d) Diverger (CE and RO)" (Hwang & Henson, 2002, p. 4). After analyzing 110 articles, the authors found there were considerable problems with reliability, enough that "continued use of the LSI should be considered questionable at best" (Hwang & Henson, 2002, p. 15).

In their review of general learning style research, Pashler et al. (2008) argued that to verify learning styles as a valid tool, very specific research methodology must be followed. They asserted that research must be conducted where students are identified by learning styles and randomly assigned to groups where different learning strategies are implemented. If learning styles are valid, they concluded, students in the group that corresponds to their learning style

must perform better than other students. Since they have found few studies that have utilized this method, none of which produced these results, Pashler et al. (2008) argue that there is not sufficient evidence justifying the use of learning styles as a determiner in instructional differentiation.

Although not an academic work, Riener and Willingham's (2010) article succinctly sums up the major criticisms of learning styles. They started with the four claims of learning styles with which they agree. The first was that "learners are different from each other" (Riener & Willingham, 2010, p. 33), leading to the need for instructional differentiation. The second claim was that students have different interests. The third claim was that student background impacts learning. The final claim was that "some students have specific learning disabilities, and these affect their learning in specific ways" (Riener & Willingham, 2010, p. 33). Although the authors claimed "learning styles do not exist" (Riener & Willingham, 2010, p. 34), they did not argue that this means students are the same. They argued that background, ability, and interest are the primary generators of learning differences between students (Riener & Willingham, 2010, p. 34). Their contention is similar to the argument seen earlier that there is no empirical evidence that students perform better when taught with a strategy designed for their particular style (Pashler et al. 2008). Overall, this seems like a valid criticism of learning styles.

2.8 GATEWAY COURSES

2.8.1 Importance of Gateway Courses on Student Retention

Research has demonstrated the importance of gateway courses for long-term student success. In his recent study, Flanders (2017) examined the importance of gateway courses for retention, finding that freshmen students who both declared a major and successfully completed a gateway course were more likely to enroll in the following semester than those who did not.

This clearly demonstrates that gateway courses are part of a larger complex system; in this case the students' academic career. Although the focus thus far has been on specific courses as complex systems, education as a complex system obviously transcends individual classrooms to encompass the students' overall educational experience.

McGowan et al. (2017) examined the role of faculty development in creating gateway courses that were engaging and promoted student success, yet it is here because they contextualize their argument with a careful examination of the importance that these types of courses have for student success, including being obstacles for student completion of programs. Shernof et al., (2017) used flow theory to examine engagement as an influencing factor for student success in gateway courses. The authors found that students who performed activities such as "taking notes, actively listening to the lecture, or working on problems" (Shernof et al., 2017, p. 18) were more engaged in learning.

2.8.2 Improvement of Gateway Courses

Berg and Hanson (2017) emphasized the role of institutional research (IR) centers in reforming gateway courses. They argued that IR can target stakeholders at multiple levels**,** including learners and instructors amongst others, and gather support for reform that would be otherwise difficult to recruit (Berg & Hanson, 2017). They concluded that IR performed a vital role in gateway course reform in their study by "informing the work with local evidence at each point in the process" (Berg & Hanson, 2017, p. 39).

Brookins and Swafford (2017) also examined gateway course improvement, but they took a route unexplored by other researchers. They examined the role of academic discipline associations in reforming gateway courses. Using a case study approach, the authors explored the role that the American Historical Association could play in reforming history gateway courses.

The authors found that discipline societies are vital in leveraging discipline specific expertise and knowledge within the context of gateway course reform.

Rife and Conner (2017) studied an effort at a community college to link gateway courses into larger pathways, sequences of courses that lead to credentials and offer students support for success. They found that faculty leadership was vital in course reform in the context of the pathway redesign. This is similar to the study by Koch et al. (2017) that examined gateway course reform in the context of systems theory, finding that the institution where their study took place emphasized the interconnection of gateway courses and institutional systems as a whole, creating an environment where reform was possible because of a shared effort.

2.9 SUMMARY

2.9.1 Restatement of Research Gap

As has been demonstrated, there is abundant research regarding delivery modalities, including their perspective effectiveness (Terras et al., 2012; Todd et al., 2017); student and faculty perceptions (Badri et al., 2016; Chiasson et al., 2015; Crawley et al., 2009; Glass, 2017; Wright, 2017); leading programs (Beaudoin, 2016; Diamond, 2008), designing programs, (Chipere, 2017; King & Boyatt, 2015), implementing programs (Bosch et al., 2015; Romanenko & Nikitina, 2015); and pedagogy and learning (Baggaley & James, 2016; Lai, 2015; Li, 2008; Shearer et al., 2015). Within this larger context, there is ample research about adaptive courseware, including types (VanLehn, 2011); impact, (Brusilovsky et al., 1998; Truong, 2016); and tools and systems (Hsieh et al., 2013; Koedinger & Aleven, 2007). As a central component of adaptive courseware, learning styles (Claxton & Murrell, 1987; Swanson, 1995) and multiple intelligences (Gardner, 2011; White, 2008) have also received adequate research coverage. Finally, the review examined research regarding the importance of gateway courses to student

success throughout their career pathway (Flanders, 2017; Shernof et al., 2017), and some basics of courseware reform (Berg & Hanson, 2017; Koch et al., 2017; Rife & Conner, 2017).

While this may appear to demonstrate that there is little room for further research, such a conclusion would be ill-informed. In their report to the Bill and Melinda Gates Foundation regarding the impact of adaptive courseware within gateway courses, Yarnall et al. (2016) reported that some adaptive courseware implementations resulted in "slightly higher average course grades" (p. ES-ii), while others had no impact, nor did they find that the courseware substantially impacted course completion rates. Finally, they found about half of four-year institution students "reported that they had made positive learning gains" (Yarnall et al., 2016, p. ES-iii), while only 33% of the same types of students recounted satisfactory experiences with the courseware. Similarly, Liu et al. (2017) examined the effectiveness of adaptive courseware in biology, chemistry, math, and information literacy, finding that the intervention was effective in the chemistry course, but not in the other disciplines.

Although there has been research regarding student success and experience with adaptive courseware in gateway courses, there has been no research about how students have used the courseware within these course types. Furthermore, this review would argue that even if such research did exist, the theoretical and conceptual frameworks utilized by most researchers within this field are insufficient to provide a meaningfully rich analysis of the interactions between the various nodes within the system. While other studies have examined how adaptive courseware has impacted student performance, without examining how students actually interacted with the courseware, this study will attempt to provide some illumination to a hitherto neglected aspect of adaptive courseware research—the complex interaction between the students, the content, and the courseware, as the students create meaning.

This study will use aspects of complexity theory to examine the complex interactions between the students, the courseware, the content, and the instructors. The characteristics emphasized will be internal diversity, internal redundancy, neighbor interactions, decentralization of control, positive and negative feedback loops, the flow and preservation of information, stability, connections, and scale. This review section has demonstrated that these characteristics are particularly evident throughout the previous research regarding modalities, adaptive courseware, learning styles, multiple intelligences, and gateway courses.

So, as has been demonstrated, there has been no identified research related to how students use adaptive courseware in relation to their success and their perceived experience with it. To examine this gap, this study will utilize complexity theory to explore the interactions of the various characteristics inherent in this complex system with the diverse nodes of this particular case. This is the research gap that this project will attempt to bridge. As such, the theoretical framework, will allow the researcher to explore the densely complex nature of introducing an adaptive courseware into a gateway course. This exploration will illuminate how the nodes of the didactical tetrahedron—learner, teacher, content, and technology—interact to create a complex learning environment that provides learning opportunities that are greater than the individual elements would suggest.

Chapter 3: Methods

3.1 Purpose of Study

The purpose of this study is to fill the gap that exists in the research regarding adaptive courseware in biology gateway courses. While there is research concerning the effects of adaptive courseware on student learning (Yarnall et al., 2016), there is no research that examines how students interact with the courseware and how that connects to their academic performance.

This study uses the lens of complexity theory (Mason, 2008b; Mason, 2009) to focus on how the interactions between the students and the system combined to affect student performance in a manner that is greater than the whole. These interactions are between the learner, the teacher, the content, and the technology, the four nodes of the didactical tetrahedron (Ruthven, 2012), as was discussed in Chapter 1. These four components are the critical variables of effective instruction, and a better understanding of their interactions could benefit instruction using adaptive courseware in particular, and online instructional strategies in general.

It is important to note that complexity theory is not a "metadiscourse—that is, an explanatory system that somehow stands over or exceeds all others" (Davis & Sumara, 2014, p. 7), but rather it is an approach that allows the researcher to "to embrace, blend, and elaborate the insights of any and all relevant domains of human thought" (p. 7). Davis (2008) makes a clear case for why complexity theory is a good fit for education researchers. While, he does admit that education has a reputation for implementing theories in research that are poor matches for education research (Davis, 2008), he argues that this is not the case in this instance. For Davis (2008), the simultaneities in education, the phenomenon that happen concurrently in a given context, are ideal for complexity theory because it allows researchers to go beyond the binary thinking that plagues so much education research. In the context of this study, complexity theory,

particularly within the conditions that are emphasized here, allowed the examination of the interactions between the learner, the instructor, the content, and the technology in such a manner that explores how these four nodes interact to create a comprehensive learning environment.

3.1.1 Primary Research Question

The primary research question for this project was: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting?

3.1.2 Subquestions

As was presented in chapter one, the didactical tetrahedron has been used in various ways to examine the relationships between learner, teacher, content, and technology (Ruthven, 2012; Tchoshanov, 2013). Furthermore, this paper has argued that the nodes in this model correspond to the primary entities that form the complex system being studied here. Ruthven's (2012) didactical tetrahedron construct is interesting because it echoes Mashaw's (2012) model that he developed to measure an online course's effectiveness that utilized the context of the learning, the instructor, the student, the technology, interpersonal relations, and the various advantages and disadvantages of the modality—all features that fit within one of the nodes of the tetrahedron.

In order to explore the relationship between these nodes more deeply, three sub-questions have been developed:

1. How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments?
2. How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection?

3. How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection?

3.2 Research Design

3.2.1 Convergent Design

This study uses the QUAN → QUAL convergent design (Creswell & Plano Clark, 2018). This method is one of the mixed method approaches described by Creswell and Plano Clark (2018). While definitions of mixed methods have evolved over the last 30 years, in general, mixed method studies attempt to help researchers corroborate and explain results. This method is used in instances where the researcher needs to more fully involve participants or compare instances (Creswell & Plano Clark, 2018).

The QUAN → QUAL convergent design is simultaneous, with the quantitative and qualitative portions of the study occurring at the same time. In this project the qualitative portion of the study occurred during the same window when the quantitative data—including the LMS and adaptive courseware data, such as time spent in a given activity or the pathway a given participant took through a particular module, was collected. The qualitative portion of the study consisted of semi-structured interviews with 21 participants and follow-up interviews with five of those participants.

In this method, either the quantitative or qualitative portion of the study can be emphasized (Creswell & Plano Clark, 2018). In this study, however, neither data collection method was more important than the other. This study will enumerate the connections between this method's strengths and weaknesses as factors in choosing it later, the primary reason this method was chosen was because of its convergent nature. In trying to answer the following question—What is the relationship between student behavior and performance when using an

adaptive courseware system in a gateway biology course in a four-year university setting? —this study requires a method that allows for the convergence of data to more fully explore these relationships. The quantitative data identified the connections between behaviors and performance through the LMS and adaptive courseware data. The qualitative data provided a more nuanced view of these relationships, given the nature of the data itself—the actual words of the participants. Their responses to the interview questions detailed their individual behaviors within the comprehensive learning environment.

The quantitative and qualitative data were collected simultaneously, but the analysis of the two data sets took place separately, with the findings eventually converged to provide a more complete picture of the participants' relationship with the adaptive courseware, the LMS, and the content.

3.2.1.1 Research Method Justification

Creswell and Plano Clark (2018) enumerate four conditions that make this an ideal choice for the researcher, including when data collection time is limited, when both types of data from all participants are required, when the individual researcher has knowledge of both types of research, and when the research team members have skills in both types of research as well. For this study, the researcher has adequate expertise in both quantitative and qualitative methods through earlier projects to adequately implement this method. Due to the restrictions on research due to COVID, the necessary changes to the IRB created a shorter period of time than originally planned. During the pandemic, FTF interactions were limited globally. This limitation affected higher education in various ways, from choices of delivery modalities to research. For this study, the first effect the pandemic had was on the ability of the researcher to conduct interviews in person. University restrictions on FTF interaction in research and instruction caused the

researcher to amend the IRB to include electronic interviews. Second, COVID affected this study by forcing the participants to take the biology course online rather than FTF. This in turn created two changes. First, many of the participants were taking the course in a modality that they did not prefer, creating new learning challenges. Second, this study was originally designed for a hybrid learning environment, where the participants engaged in the course online and FTF. The restrictions emplaced because of COVID forced the researcher to adapt the study to a purely online modality.

The theoretical framework of this study necessitated the use of the convergent design method. Since the study explored the relationships between the nodes on the didactical tetrahedron, a method that allowed for the combination of data to provide a clearer picture of these interactions was necessary. This study explored the quantitative data for the conditions of a complex system, emphasizing the dyads discussed earlier—specialization, comprised of internal diversity and internal redundancy; trans-level learning, comprised of neighbor interactions and decentralization of control; and enabling constraints, comprised of randomness and coherences. The qualitative portion allowed the researcher to more fully explore the participants' interactions with the system and any manifestations of these dyads.

3.2.1.2 Strengths of the Design

Creswell and Plano Clark (2018) argue that there are four primary strengths of the convergent design. Each of these strengths is evident within this study. First, the design is both intuitive and popular among mixed-methods researchers (Creswell & Plano Clark, 2018). Second, it is a very effective design that allows for simultaneous collection and analysis of data (Creswell & Plano Clark, 2018), a primary concern given the time constraints in this study. Third, the reliance on separate collection and analysis of the two types of data make it an ideal

choice for team research. Although this was a solo project, this advantage also benefited the researcher given the time constraints of the study. Fourth, the ability of the design to enable "the direct comparison of participants' perspectives" (Creswell & Plano Clark, 2018, p. 71), the qualitative data, with the "perspectives drawn from the researchers' standpoint" (p. 71), the quantitative data, allowed the researcher to collect the data within the face of a rather aggressive timeline, and analyze it with the comprehensiveness the theoretical framework demands.

3.2.1.3 Design Limitations

While the strengths of the research design facilitated the use of complexity theory as a theoretical framework, the weaknesses of the design did not hinder the use of this framework. Creswell and Plano Clark (2018) enumerated three weaknesses in this approach. First, they stated, "differences of sample sizes" (Creswell & Plano Clark, 2018, p. 71) must be addressed because the difference in sample sizes may cause difficulty when the data sets are merged and compared. Fortunately, they provided an ameliorative solution to this difficulty, primarily "collecting large qualitative samples" (Creswell & Plano Clark, 2018, p. 71), which is what this study did, with twenty-one initial interviews and five follow-up interviews. Complexity theory provides a framework in which the researcher can focus on the particular conditions inherent in the complex system, emphasizing the interactions between the learner, the instructor, the content, and the technology. In turn, this allows for focusing on these interactions: internal diversity, internal redundancy, neighbor interactions, distributed control, randomness, and coherence (Davis & Sumara, 2014), and will provide a focus on relationships in such a way that the differences in data sets can be mitigated.

Second, Creswell and Plano Clark (2018) argue that there can be difficulties in merging "a text and numeric database" (p. 72). They suggest, "researchers design their studies so that the

quantitative and qualitative data address the same concepts" (p. 72). Again, the theoretical framework can help mitigate this weakness because it provides a sound set of concepts around which the study was planned.

Third, the researcher may "need to explain divergence when comparing results" (Creswell & Plano Clark, 2018, p. 72) if the "quantitative and qualitative results do not agree" (p. 72). While this would normally act as a weakness, the choice of theoretical framework removes this as an obstacle, because it provides the focus, in this case: specialization, trans-level learning, and enabling constraints, which were identified, analyzed, and addressed through the divergent nature of the data types.

3.3 PARTICIPANTS

3.3.1 Sampling

Sampling is a vital criterion in quantitative research, because the method used can affect whether or not the research can be repeated (Delice, 2010). Not reporting the sampling method has been cited as a problem in quantitative research (Delice, 2010). Given that sampling is included in the third domain of O'Cathain's (2010) examination of research quality, data quality, it is vital for this project to provide adequate justification for both the quantitative and qualitative portions of the research.

All of the participants were chosen from one section of biology. This course is one of the gateway courses chosen for inclusion in the APLU grant. This grant's purpose is to implement adaptive courseware in gateway courses. Biology 1305 was chosen as part of this grant because of the DFW rates associated with it.

3.3.1.1 Sampling for Quantitative Portion of the Study

One online section of Biology 1305 was chosen for this study. The course was originally intended as a FTF course. However, the limitations on FTF courses put into place by the university during the Spring 2020 semester and extending into the 2020-2021 school year prevented this course from being delivered through this modality. The quantitative data, including student LMS and adaptive courseware usage data, included 60 of the students enrolled in the chosen section. There were three sections of biology chosen to implement adaptive courseware as part of the APLU grant. Of these three, two courses used the CogBooks system. Of those two, one professor agreed to take part in the study. This course had 130 students in it and 60 of those turned in the required informed consent protocol forms, with six of those students not active in CogBooks during the data collection window.

3.3.1.2 Participant Recruiting for Qualitative Interviews and Focus Groups

As Guetterman (2015) has pointed out, researchers such as Emmel (2013) have made it clear that sampling for qualitative research is not a discrete process planned and implemented during specific phases of the project. Rather, it is an emergent process that evolves as the project itself does. Given the theoretical framework of this study and the complex nature of the interactions between the student, instructor, content, and technology, the nodes on the aforementioned didactical tetrahedron, defining the sampling procedure for the qualitative portion of the study has been somewhat problematic. With this difficulty in mind, this project will utilize a method that will both reflect the necessities afforded the overall theoretical framework as well as be responsive to the needs inherent in the QUAN→QUAL convergent methodology.

This portion of the study engaged 21 participants, who were enrolled in the chosen section of Biology 1305 that is using the adaptive courseware. The students chosen for this portion of the study are typical examples of purposeful sampling (Creswell, 2013; Creswell & Plano Clark, 2018), and representative of a "typical case" (Seidman, 2013, p. 57) in that they are enrolled in the course at the time of the study. Emmel (2013) emphasizes the pragmatic nature of purposeful sampling, and how "it is not driven forward by theoretical categories, but practical and pragmatic considerations" (p. 33). Although it may seem unusual to choose such a pragmatic method, when every other decision has been so deeply rooted in this study's theoretical framework, the aggressive timeline for the study necessitated this approach. Also, as seen in *Design Limitations* (Section 3.2.1.3), the selection of participants within the given pool should not affect the results.

3.4 Data Sources

Through the course itself, the researcher had the system data from the course, including data from the LMS and the adaptive courseware. This quantitative. included time spent on activities, assignment scores, the number of times a given activity was accessed, and student confidence levels with specific content. This data was analyzed when the semester was completed. Semi-structured interviews (Merriam & Tisdell, 2016) and follow-up interviews were utilized for the qualitative portion of the study.

3.4.1 Quantitative Procedures and Data Sources

For the quantitative portion of the study, the primary data was student CogBooks usage data and LMS usage data. The LMS the university uses is Blackboard, a common course delivery solution at the university level. The university offers online resources for students to help them learn how to navigate this resource. The Blackboard data included the dependent

variables, Final Average, the final grade earned by the participant including all LMS assignments and assessments as well as the participation grade earned by completing the assigned CogBooks activities, and Exam 4, which assessed the students' mastery of all content taught during the data collection period. The Blackboard data also included the independent variable—LMS Content Hits, which refers to the number of times participants clicked on activities available through the LMS, including the link to CogBooks activities.

The adaptive courseware used in the course is CogBooks. This adaptive courseware has several features designed to improve student performance in biology courses. Launched in 2005, CogBooks provides whole course instruction; company developed content and the ability to incorporate OER; various professional support services, including online and phone support, professional development, and course development services; and a variety of student collaboration tools (Newman et al., 2016). This system also provides anytime textbook access for students, pre-created modules for teachers to implement, highly rated content, various alert protocols to warn teachers when students appear to be underperforming, real-time assessment and feedback, engaging content, and a focus on skills (CogBooks Courseware, 2020). This study used various metrics from the adaptive courseware, including data on total time individual participants spent within the courseware; average confidence level, which records the average ranking the participants placed upon their confidence with specific content; and CogBooks activity hits, which represents the number of times the students accessed individual CogBooks resources. Each of these metrics was used as independent variables in this study. The lone dependent variable derived from CogBooks data was CogBooks average score, which measured the participants' average from all CogBooks activities and assessments completed during the data collection window.

3.4.2 Qualitative Procedures and Data Sources

For this portion of the study, data was collected in two primary ways. First, semi-structured interviews were conducted with participants chosen from the same section of 1305. The principal objective of these one-on-one interviews was to examine the individual participant's perceptions of their interactions with the system's—learners, instructors, content, and technology—in the context of specialization, learning, and constraints. Second, follow-up interviews were conducted with five of the original 21 qualitative participants. The main objective of the follow-up interviews was to examine the interactions between the learner and her peers and instructor, how CogBooks could have been used differently in class, and how the participants thought CogBooks directly influenced their performance in class.

3.4.2.1 Semi-Structured Interviews

There were 21 participants asked to complete an interview regarding their experience with the adaptive courseware. Of these 21 participants, five of them also participated in follow-up interviews. Initial interviews took approximately 40 to 60 minutes, with the follow-up interviews taking about 15 minutes. The initial interview questions dealt with the participants' interactions with CogBooks, Blackboard, and the professor provided resources. The questions emphasized the participant's perceptions of her interactions with the adaptive courseware system, the LMS, and the professor's content, particularly the perceived randomness or coherence of this content in the absence of FTF instruction.

Participants were given the opportunity to participate in follow-up interviews. These follow-up interviews took place during the last two weeks of the semester. The researcher scheduled these interviews through the participants' university email.

3.5 DATA ANALYSIS

3.5.1 Quantitative Statistical Methods and Analysis Procedures

Quantitative data was collected from November 27 to December 15, 2020. The first exploration into the data was through descriptive statistics. After this initial exploration, the researcher then tested for correlations. Initially Pearson's correlation coefficient was going to be used when the data was normally distributed and the data was a continuous variable (Field, 2018). When the data consisted of ordinal, interval, or ratio variables, or the assumptions for Pearson's coefficient were not met, Spearman's correlation coefficient was used (Field, 2018). With the variables used, the assumptions for Pearson's coefficient were not met and the study relied on Spearman's *r*.

3.5.2 Qualitative Coding and Analysis Procedures

As mentioned earlier, the study design used here, QUAN→QUAL, is meant to allow the researcher to converge the qualitative and quantitative data (Creswell & Plano Clark, 2018). Interview recordings were transcribed as soon as possible after each interview, so that the researcher could begin analysis of this data in order to allow it to be combined quickly with the emerging qualitative data pool. The investigator also took notes during the interviews. These field notes were compiled for two primary reasons. First, field notes are essential environments for the researcher to reflect on himself (Delamont, 2016). As such, the researcher used field notes to explore his reflexivity, an important aspect of education research that utilizes complexity theory as its theoretical framework. Second, field notes play an important role as mediator between the researcher and participant (Delamont, 2016). For this study, the field notes helped illuminate the connection between learner, instructor, content, and technology as portrayed in

both the initial and follow-up interviews because they provided the researcher with a dynamic source that could be revisited and reanalyzed throughout the process.

3.5.2.1 Coding

After all data had been gathered and recorded, for both the interviews and follow-up interviews, coding began. According to Creswell and Plano Clark (2018), "coding is the process of grouping evidence and labeling ideas so that they reflect increasingly broader perspectives" (p. 214). This study used a combination of descriptive coding, in-vivo coding, and process coding. This study did not utilize qualitative data analysis software in order to allow the researcher to be fully immersed in the data firsthand, thereby more fully experiencing the system's complexity.

First, the study used process coding because it emphasizes action, using "gerunds exclusively to connote observable and conceptual action in the data" (Saldaña, 2016, p. 296). This coding method is ideal for this study for two reasons. First, the focus of the study is how students interacted with the courseware and made meaning from the content. Second, as we have seen elsewhere in this chapter, this study emphasized the complexity theory conditions of specialization, which emphasizes "the tension of diversity and redundancy" (Davis & Sumara, 2014, p. 135), trans-level learning, which includes "enabling neighbor interactions," and enabling constraints, which includes "balancing randomness and coherence." As one can see, each of these conditions includes action. Specialization's action is the propagation of the system created through the diversity and redundancy of the system's nodes. Trans-level learning's action is the activity generated through the node's interactions. Enabling constraint's action is how the system is maintained through the nodes' modified action. The actions embedded in each of these conditions made process coding an ideal choice, given that it emphasizes action as well.

According to Saldaña (2016), descriptive coding, where labels are assigned "to data to summarize in a word or short phrase . . . the basic topic of a passage" (p. 292), is "appropriate for virtually all qualitative studies" (p. 292). It was particularly useful in this case because this coding method allowed the researcher to begin to organize the data along the conditions of complexity theory, particularly the dyads identified earlier—specialization, trans-level learning, and enabling constraints (Davis & Sumara, 2014).

In vivo coding, which "uses words or short phrases from the participant's own language in the data record as codes" (Saldaña, 2016, p. 295), was used because of the academic language associated with the discipline. It is also a good choice because some terms related to the conditions of complexity theory occurred in the data, including diversity, redundancy, interactions, decentralization, feedback, information flow, stability, connections, and scale. While not all of these attributes are components of the dyads, which this work emphasizes, they were still noted during coding to help the researcher gain as complete a picture of the participants' interactions with the system as possible.

3.5.2.2 Analysis Methods

After initial coding, analysis continued through identifying themes (Creswell & Plano Clark, 2018). After the themes were identified, the researcher continued the analysis by grouping the themes "into even larger dimensions or perspectives" (Creswell & Plano Clark, 2018, p. 214) that were then "linked to each other to form a larger story" (p. 214). These linkages were examined through the lens of complexity theory, to determine whether they were examples of specialization, trans-level learning, or enabling constraints in order to demonstrate how the interactions of the various nodes in the system create a whole that is greater than the sum of the parts.

3.6 EVALUATION OF RESEARCH

Although Creswell (2011) did not specifically list evaluation of research as one of the many mixed method controversies he enumerated, he did argue that there is some question among researchers about the value, if any, this approach brings to researchers. While an examination of this controversy, to borrow his word, is beyond the scope of this paper, some attention needs to be paid to how the value of this study will be determined.

In order to determine this study's value, it utilized O'Cathain's (2010) eight domain framework as its basis for evaluation. The first domain is planning quality (O'Cathain, 2010). The primary marker of success in this domain is a thorough literature review (O'Cathain, 2010). This paper's literature review critically examined each particular dimension of the topic, from background information about delivery modalities, to issues concerning gateway course reform. The second domain is design quality (O'Cathain, 2010). The mixed method chosen, QUAN→QUAL was described earlier. Each of the advantages and disadvantages of the method were discussed in relation to this particular study's needs and in relation to the theoretical framework. The third domain, data quality (O'Cathain, 2010), concerns adequate sample size and data analysis. This project used a sample size of 60 participants out of a population of 130 for the quantitative portion. This study had 21 participants for the qualitative portion of the study. For the qualitative data analysis, it used in vivo, descriptive, and process coding. Interpretative rigor (O'Cathain, 2010) is the fourth domain. The qualitative data was analyzed six individual times, including an initial reading, one reading using in vivo coding, and two sessions of descriptive and process coding. Using complexity theory as the theoretical framework ensured that there was an adequate interpretative structure to ensure rigorous analysis. The fifth domain, inference transferability (O'Cathain, 2010), is possibly the weakest domain for this study. Given

the nature of the study, transferability of findings across context, groups, or time is questionable. While convergent design was used to provide a clearer picture of a given problem (Creswell & Plano Clark, 2018), transferability to other problems can be challenging. However, there was strong theoretical transferability given the complexity of the system under examination. Reporting quality (O'Cathain, 2010), the sixth domain, is strong given the study's reliance on complexity theory and the QUAN→QUAL convergent method. The framework and method allowed the researcher to combine the quantitative and qualitative findings to illustrate the synergy between the nodes of the didactical tetrahedron since a component of this domain is that the "whole is more than the sum of its parts (O'Cathain, 2010, p. 545). The seventh domain, synthesizability (O'Cathain, 2010), focuses on the appropriateness of the method as a choice. It has been clearly demonstrated throughout these three chapters that the QUAN→QUAL method is the appropriate choice given the subject matter, the theoretical framework, and the nature of the data. Utility (O'Cathain, 2010), the eighth domain, concerns how well the findings will be used by other researchers. At this point, there is no method to adequately measure how well this research will be consumed in the future, but as discussed in the first chapter, this study's findings do relate to how educators incorporate educational technology.

O'Cathain's (2010) eight domains provided a comprehensive set of criteria to thoroughly evaluate this study. From the early stages of planning and design, through data quality, interpretive rigor, transferability, reporting quality, and synthesizability, to the final utility of the study as a whole, these domains facilitated the creation of quality research. This study was conducted from start to finish with these criteria as the basis for all major decisions.

3.7 Ethical Considerations

The primary, practical ethical considerations for this study, including confidentiality of participants and data, and risks and benefits to participants are covered in the institutional review board (IRB) approval process, all of which will be considered later in this section.

Along with these practical ethical considerations that are inherent in any research study, complexity theory raises its own ethical concerns, particularly ontological issues. Horn (2008) states that he "readily concedes the difficulty posed in deriving direct causal explanations or predictive proof for complex phenomena within which he is embedded" (p. 141). In other words, given the complex nature of interactions within systems, there is too much happening "beyond the scrutiny of an observer" (Horn, 2008, p. 141). However, by paying particular attention to reflexivity (Creswell, 2013) and his positionality, in connection with the theoretical framework, the researcher was able to contextualize his position with the complex interactions within the rest of the system.

3.7.1 Confidentiality of Participants

All participants were given numbers in all documents other than the informed consent document. Pseudonyms were randomly assigned to participants after the data was transcribed. The pseudonyms and numbers were not recorded on the informed consent document. The informed consent documents were kept separate from all other data collected. Given the required limits to face-to-face research due to COVID restrictions, all interviews were conducted through Zoom. They were not recorded using Zoom features; rather, the researcher recorded them locally on a digital audio recorder. After agreeing to participate through a Google form, each participant was contacted through their university email and provided with an informed consent document, a link to a sign-up page, and a number. The number was used instead of their name to schedule a

time for a Zoom meeting. When the participant returned the informed consent form, it was downloaded unto a flash drive and kept in a secure location. The participant's name was not noted in the recording, fieldnotes, or any other location. The researcher only referred to participants by their number in documentation. During the writing process all participants who were directly referred to were assigned random pseudonyms. Participants were able to skip any question that they felt might cause them discomfort during the interviews.

The quantitative data from Blackboard had all identifiable student information and the data pertaining to all the students who did not give informed consent for the quantitative portion of the study removed. The quantitative data from CogBooks had all information related to individual identification removed. CogBooks provided only that user data that corresponded to the user list given to it from students who had signed the required informed consent protocol forms.

3.7.2 Confidentiality of Data

The quantitative data was available through the adaptive courseware system. No usage data, including how the individual participants navigated the adaptive courseware, or performance data, including student grades, was identifiable with specific students.

For the qualitative data, all digital records, including the digital audio files of the interviews and the follow-up interviews were kept on a password-secured removable hard drive, which was locked in a secure cabinet inside a locked room. The recordings were erased after the study had been concluded. Only the primary investigator had access to the digital records. All other records, including field notes, or other written accounts of the study were kept in the same locked cabinet. All field notes, interview transcriptions, or other data were identified by the participants' pseudonyms. Only the primary investigator had access to the non-digital data.

Consent forms were stored in a separate location, in a locked cabinet. Pseudonyms were documented on a key and related to the individuals only through their assigned numbers. The pseudonym key was kept with the digital records and separate from the consent forms. The pseudonyms were not recorded on the informed consent documents or on any document identified by the participants' names.

3.7.3 Potential Risks to Participants

Degree of risk posed by participation in this study is considered minimal. The primary potential risk stemming from participation in this study is the risk that the confidentiality of participants' responses might be compromised. While the compromise of this information would not put the participants at risk for losses of social status or income, all efforts were made to ensure confidentiality of records.

Participants did not face major risks of emotional stress due to the nature of the questions. The questions posed in this study, both in the initial interviews and the follow-up interviews, required the participants to expand upon their experiences with the adaptive courseware, each other, and the instructor. If at any time participants were unable to answer a question because they were uncomfortable or because it provoked unpleasant memories, the participant was able to skip the question or terminate the interview. In the unlikely event that participants became upset discussing their adaptive courseware usage or activities in the course, the primary investigator would have referred them to university counseling services, though this did not occur. There was no deception involved in this study.

3.7.4 Potential Benefits to Participants and Researchers

There were no direct benefits to participants in this study. This study may provide educators and researchers with a clearer view of how adaptive courseware operates as part of a complex system, opening a pathway for new implementations of instructional technology.

3.7.5 Summary of Methods

This study was designed to fill in the research gap related to adaptive courseware in biology gateway courses. To this end, the primary research question was: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? This study utilized a QUAN→QUAL convergent design, in which the quantitative and qualitative data occurred at the same time. The participants in this study came from one section of Biology 1305. The quantitative data consisted of Blackboard data and CogBooks data from 60 participants, not all of whom were active during the data collection window. The qualitative data consisted of semi-structured interviews with 21 individuals and follow-up interviews with five of those 21. The quantitative data was analyzed Spearman's correlation coefficient. The qualitative data was analyzed using descriptive, in-vivo, and process coding. Every effort was made to ensure confidentiality of participants and data. The study posed minimal risk for the participants.

Chapter 4: Findings

Given the nature of this study's methodology, qualitative and quantitative findings were merged in order to uncover the interactional dynamics between the participants, the adaptive courseware, the LMS, the course content, and the professor. Within the context of the didactical tetrahedron, the participants correspond to the learners, the adaptive courseware and LMS correspond to the technology, the course content to the content, and the professor to the teacher. These complexities will further be examined to demonstrate how they related to student behaviors, which, in turn, affected student performance.

During analysis three salient themes were identified that illustrated the system's inherent complexities, as seen in Figure 4.1. In the introductory section of each theme, relevant quantitative data is also included to provide additional insight to the qualitative discussion. By including the quantitative data with the primary themes, rather than individual subthemes, the larger connections between the two data types are emphasized.

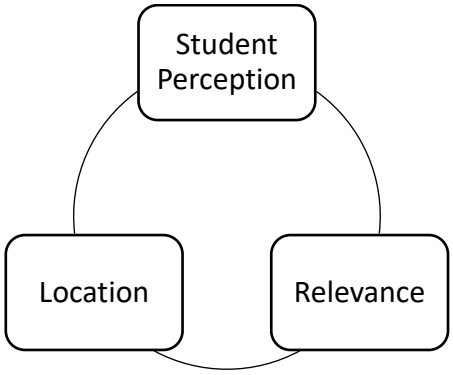

Figure 4.1. Themes Identified in the Qualitative Data

Student perception is the first theme, which, as reported earlier, is frequently a focus in distance education literature (Robinson, 2017; Tichavsky et al., 2015; Wright, 2017). While student perceptions in a given educational environment can encompass a myriad of aspects, such as how perception affects the choice of delivery (Badri et al., 2016; Robinson, 2017; Tichavsky

et al., 2015; Wright, 2017), student perception of the delivery modality's effectiveness (Carver & Kosloski, 2015; Fish & Snodgrass, 2015; Jahng, 2004), and the relationship between perception and the student's individual learning experience (Agdas et al., 2014; Ganesh et al., 2015; Horzum et al., 2015; Lin & Tsai, 2011; Sobhy & Megeid, 2014), this study identified perception as a key theme rooted simultaneously in several aspects of the course. These include the students' perceptions of themselves as learners, the adaptive courseware system, the LMS, the professor-provided content, and the professor. These four facets of the course were, in turn, evident in the subthemes the researcher identified relevant to perceptions—participant's perception of the system's ease of use, the system's restrictiveness, and their peer's practice. Along with this theme, the researcher included the quantitative data regarding the correlation between the students' final average and the total time spent on CogBooks, the correlation between final average and the number of times the participants accessed resources through the LMS, and the correlation between the students' final average and the number of times they accessed adaptive courseware activities. These correlations provide another dimension of the role of perception in students' usage patterns with the adaptive courseware and the LMS.

The second theme identified in the qualitative data was relevance, which also has strong multifaceted elements embedded within it. While it encompasses how the participants navigated the adaptive courseware and other resources in relation to the relevance to their goals, it is more complex than it initially appears. The participants exhibited a heightened sense of relevance, which mediated their system use. The participants navigated the complex system created by the nodes on the didactical tetrahedron using relevance to reconstitute the entire system to achieve their goals, including their short-term goals, long-term goals, and immediate learning needs. For example, by mediating their choice of resources with the needs determined by a specific goal,

such as passing a given module, the participants created systems customized for particular situations. These goals are indicative of the complexities that participants must navigate. While these goals are easily identified and defined, they reside within different time frames. Immediate learning needs are the most urgent for the participant, requiring them to grasp the material in a particular module. Short-term goals can be understood as an amalgam of immediate learning needs, where the participant must successfully navigate the entire course thereby achieving a satisfactory grade. Long-term goals are the most remote to the participants' current location, which include their plans to take additional courses within a pathway to ultimately achieving their career goals. Keeping the multi-dimensional characteristics of this theme in mind, analysis revealed three subthemes, from the prosaic to the less commonplace, including how participants navigated the system, how this navigation mediated the pursuit of their goals, and how they prioritized usefulness of sources in conjunction with the previous two subthemes.

In the introductory section regarding relevance, two correlations conducted with quantitative data are also included. The first correlation describes the relationship between students' scores on Exam 4 and the number of times they accessed resources through the LMS. The second relates the correlation between the students' score on Exam 4 and their confidence with the adaptive courseware content. Both of these correlations serve to illustrate how students utilize relevance as they navigate the CLE.

The third identified theme was location. In the context of this study, location refers to how the students position themselves within the system at different times for distinct needs, particularly the manner in which they utilized the different resources provided, including the adaptive courseware and professor provided content, dependent on external constraints on time and internal requirements related to completion of activities. Closely related to relevance in

operation, location is the ability the students have to create a space for themselves in the course in relation to the other nodes on the didactical tetrahedron, particularly the content and technology. As the findings will further demonstrate, the participants located themselves either closer to or farther from given resources and technology tools as the importance of both fluctuated in relation to the participants' needs at a particular time.

This positioning led to instances of agency, used here to refer to the ability of a given individual to interact with a particular environment "through the interplay of habit, imagination, and judgment" (Emirbayer & Mische, 1998, p. 970) to transform said environment. This generated the ideal conditions for agency, in the creation of personalized learning environments from the originally provided educational environment. Under this theme, three subsections are identified: using resources, creating space for themselves within the system, and how the participants viewed themselves as learners. During the introduction of location as a main theme, the researcher provides correlations between four vital variables. The first examines the relationship between the students' performance on Exam 4 and the total time they spent on CogBooks' activities. The second relates the relationship between the students' average scores on the CogBooks activities completed during the data collection window and the total time they spent in the CogBooks adaptive courseware system. Both correlations provide a more complete picture of how students used location within the CLE to create a customized learning space.

It is important to note at the beginning of this analysis that the dyads identified in this paper—specialization, trans-level learning, and enabling constraints—are frequently present in each of the identified themes within this study. Considering that the themes—student perception, relevance, and positioning—occur throughout the participants' interaction with the system during the duration of the course, it follows that the dyads are evident throughout the data.

Furthermore, each of the dyads frequently interacts with each other. They are not mutually exclusive. They also interact, interrelate with, and influence the other. As characteristics of a complex system, these dyads indicate how the system is created, controlled, and maintained. Since these characteristics are indicative of the different stages of the system's life cycle, they do not generally operate simultaneously. Since this particular system is so complex, these three dyads are often occurring simultaneously. To facilitate understanding of the complexity of the environment in which this study took place, the term comprehensive learning environment (CLE) will be used. The CLE incorporates the learner; each aspect of the LMS and adaptive courseware, including the content and the technology; and the teacher, with the complex behaviors these interactions entail. The CLE is the ecosystem in which adaptive learning takes root and thrives.

As the data was analyzed, it became clear that the participants viewed themselves as operating within a system constituted by themselves, their instructor, the content, and the technology—the didactical tetrahedron, but also consisting of the LMS and adaptive courseware as technologies, resources, and specific locations, and the participants' interactions with the other nodes. The CLE is more complex than the didactical tetrahedron. Because CogBooks and Blackboard were the focus of the interview questions, it became clear that, in order to understand the participants' behaviors with these tools, the entire course system, composed of each of the nodes on the didactical tetrahedron—the learner, the instructor, the technology and the content—and participants' interactions with it, needed to be understood to fully answer the research questions.

As a convergent methods study, this project seeks to examine both qualitative and quantitative data to answer this primary question:

What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? And the following subquestions:

1. How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments?
2. How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection?
3. How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection?

To answer these questions, this study sought to understand the interactions of the teacher, learner, content, and technology. To facilitate this understanding the didactical tetrahedron was further expanded to represent the interactions of these different nodes, as depicted in Figure 4.2. One can see how the learner is connected to the teacher through the content, technology, and the LMS and adaptive courseware as locations in this graphic. While this may appear to be an unnecessary complication, this graphic serves an important purpose. This depiction of the elements in the complex system constituted by the nodes of the didactical tetrahedron helps demonstrate the complexity of the LMS and the adaptive courseware system. To illustrate this complexity, two additional nodes were added to the model. These two nodes are LMS as Location and Adaptive Courseware as Location. The addition of these two nodes reflects how these two systems acted as places where the participants went to learn. Content and technology remain on this model, placed between the LMS and adaptive courseware, depicting the relationships between each node. This illustrates how these two systems also acted as content and technology for the participants.

This model was developed from the findings. The qualitative data indicated that the participants viewed the LMS and the adaptive courseware in distinct ways. First, participants viewed both as distinct places within the course. The concept of the LMS and the adaptive courseware as locations was not merely an abstract ideation to the students. The participants often talked about being in the courseware or getting into the LMS. For the participants, the LMS and the adaptive courseware were places where they learned. Second, both of these systems are constituted by technology and content. These systems deliver content through technology and are technologies themselves. The qualitative data will demonstrate that the learners in this study viewed these two systems as part of the overall learning environment, in which the LMS and adaptive courseware were both deliverers of content and the content themselves. Figure 4.2 depicts the separation of both the LMS and adaptive courseware into these three distinct aspects, while also providing a sense of their interconnections.

Along with the qualitative data, various quantitative data were gathered. This included student usage metrics from the adaptive courseware and the LMS, as well performance data, which included average score for CogBooks activities, scores on the major exam given during the data collection window, and the students' final averages. The data exploring the relationships between these variables is included along with the qualitative data to provide broader context to the qualitative findings. The quantitative findings are included with the theme to which they are related. Including them with the primary themes, rather than subthemes, demonstrates the broader connections between these two data types.

To avoid confusion, when the analysis and conclusions discuss the biology course as a complex system as depicted in Figure 4.2, this study will use the term comprehensive learning environment (CLE). The CLE contains the four nodes of the didactical tetrahedron with which

the study has previously based its discussion. However, there are important differences. In the didactical tetrahedron, technology refers to the LMS and adaptive courseware solely as technologies. The CLE encompasses the LMS and adaptive courseware as technologies, resources, and specific locations. Moreover, this term also includes the actions of the learners as they interact with the professor and these different forms of the LMS and adaptive courseware. As the data will demonstrate, the complex interactions of the participants with these nodes created and sustained the CLE.

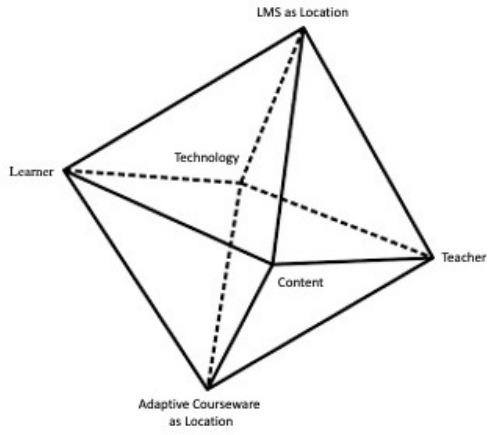

Figure 4.2. Comprehensive Learning Environment

There were two main types of resources in this course—those included in the adaptive courseware (CogBooks) and the professor provided resources. The adaptive courseware activities included readings, videos, and matching activities—which are included in individual modules assigned by the professor. The courseware was considered adaptive because it provided a variety of activities for students to utilize as they completed the modules. These modules are designed to provide a variety of learning opportunities using different media types and activity types. For example, during the course of this study, the professor had assigned Topic 22: DNA Replication. This topic included a CogBooks assignment—Module 4.1 DNA Structure and Replication that provided several types of assignments such as a video on “Experiments on DNA

as the Hereditary Model," readings on nucleotides, and quizzes on the material covered, among others. The professor provided a variety of other sources, comprising PowerPoint presentations that were the basis of the professor's recorded lectures, the recorded lectures themselves, and activities that included various exercises that stimulated higher order thinking skills. In this same topic, the professor provided a PowerPoint on DNA structure, a recorded lecture based on the PowerPoint, a YouTube video on DNA replication, a review activity, and a quiz.

4.1 Student Perception

Student perceptions were evident throughout the data in various ways. While this theme does interact with the other two themes—relevance and location—this analysis will examine it separately because perception was clearly an instance of an enabling constraint. As previously discussed, enabling constraints are those factors that limit interactions with the system in such a way that new methods of interaction, generating innovative usages of the technology and the resources, arise. Perception is an enabling constraint because it influences the users' actions and interactions with the system; thereby creating something that goes beyond the limitations of the system itself, see Figure 4.3 for a depiction of the interaction between them.

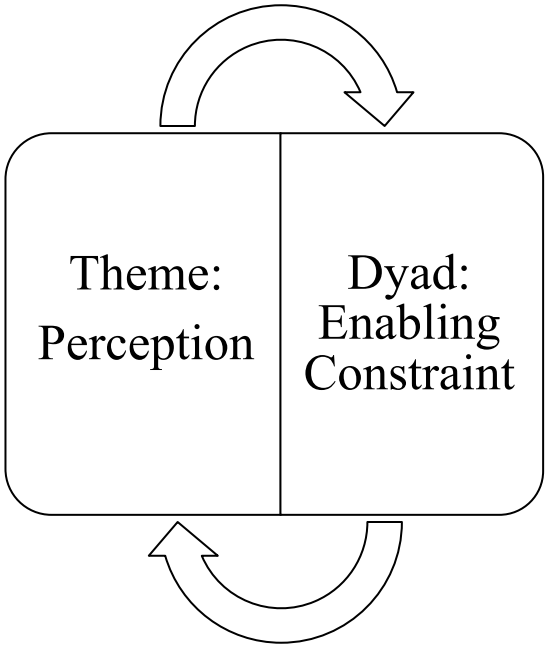

Figure 4.3. The Relationship between Perception as a Theme and as a Dyad

Enabling constraints represent the balance between randomness, those entities forcing change, and coherence, those activities that allow the system to maintain itself. The balance between the two enables the system to continue. Moreover, this continuation enables nodes within the system to use it in ways that transcend its limitations. While enabling constraints can be a difficult construct to immediately grasp, a concrete example should elucidate this somewhat paradoxical concept. One example would be black and white photography. There are inherent limitations to this media, most notably the lack of color in the finished photograph. This would typically be considered a weakness given that most people are used to vibrant, colorful depictions of events. However, a photographer who has mastered this media can create photographs that transcend a strict depiction of the subject, creating a picture that captures the emotion and meaning beyond a mere image. Clearly then, enabling constraints in this study represent those limitations in the system that allow the participant to create learning situations that transcend those situations inherent to the adaptive courseware, the LMS, and the professor-

provided resources. This theme is divided into three subthemes, including how the participant perceived the system's ease of use, how the participant perceived the system's restrictiveness, and how the participant compared their use of the system to their peers' usage, see Figure 4.4.

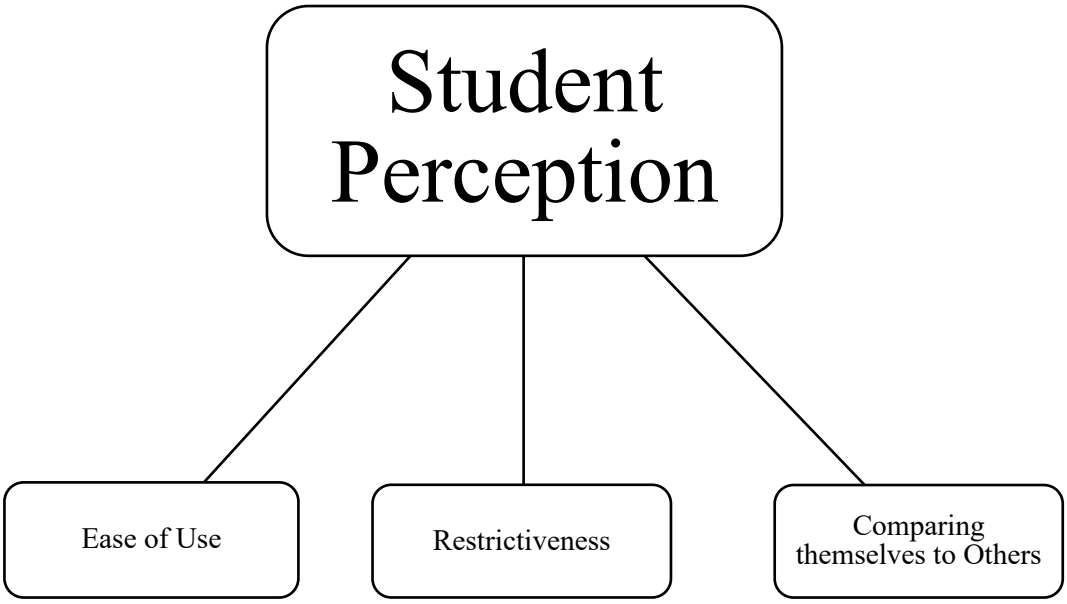

Figure 4.4. Student Perception Subthemes

As part of this theme, the correlation between adaptive courseware usage, measured by the amount of time spent in CogBooks, and the student's final average in the course, is included here because it is related to student perception. As time spent with a resource can be viewed as a measurement of a student's perceived positive perception of said source, this correlation relates perception to long-term performance in the course. As students navigated the CLE, their perception of ease of use, restrictiveness, and their behaviors compared to that of their peers mediated their resource choices. In this comparison, Final Average represents the participant's final grade in the course, including their performance on assignments and assessments within the adaptive courseware and those provided by the professor. CogBooks Total Time represents the amount of time students spent on the adaptive courseware activities during the quantitative data collection window. In this quantitative analysis, it was determined that there was no significant

relationship between the time participants spent on adaptive courseware activities and their final grade in the course, $r_s = .260$, $p = .058$, see Table 1.

Table 1: Correlation between Final Average and CogBooks Total Time

			Final Average	Cogbooks Total Time
Spearman's rho	Final Average	Correlation Coefficient	1.000	.260
		Sig. (2-tailed)	.	.058
		N	60	54
	Cogbooks Total Time	Correlation Coefficient	.260	1.000
		Sig. (2-tailed)	.058	.
		N	54	54

The quantitative data depicting the relationship between using the LMS, as indicated by content hits, and the student's final average is included here as well. Like the previous relationship, this correlation can be viewed as related to perception in that the number of times the participants accessed the LMS sources could be indicative of positive student perception of those resources. The relationship between student performance as indicated by final average and student behaviors represented by the number of times the student accessed content on the LMS is related to student perception, because it demonstrates the relationship between student interactions with the LMS and course performance. Again, Final Average represents the participant's final grade in the course, including their performance on assignments and assessments within the adaptive courseware and those provided by the professor, while LMS Content Hits is the number of times students accessed content through Blackboard, including accessing the adaptive courseware activities, as well as those activities and assessments provided directly on the LMS. As seen below in Table 2, there was shown to be a significant relationship between the participants' access of content through the LMS during this time and their final grade, $r_s = .531$, $p < .001$. This demonstrates that using the LMS tools was strongly related to better performance in the course.

Table 2: Correlation between Final Average and LMS Content Hits

			Final Average	LMS Content Hits
Spearman's rho	Final Average	Correlation Coefficient	1.000	.531**
		Sig. (2-tailed)	.	<.001
		N	60	60
	LMS Content Hits	Correlation Coefficient	.531**	1.000
		Sig. (2-tailed)	<.001	.
		N	60	60

**. Correlation is significant at the 0.01 level (2-tailed).

Related to the relationship between LMS usage and final average is the correlation between final average and CogBooks usage. Similar to the previous correlation, this one is related to perception in that the number of times the participant accessed adaptive courseware activities can be interpreted as positive perceptions of those activities. This correlation demonstrates the relationship between how the student interacted with CogBooks and how they performed in the course, with Final Average representing the participant's final grade in the course and CogBooks Activity Hits the number of times students accessed adaptive courseware activities. In this analysis, depicted in Table 3, it was shown that there was no significant relationship between the participants' access of content through the adaptive courseware during this time and their final grade, $r_s = -.015$, $p = .912$.

Table 3: Correlation between Final Average and CogBooks Activity Hits

			Final Average	Cogbooks Activity Hits
Spearman's rho	Final Average	Correlation Coefficient	1.000	-.015
		Sig. (2-tailed)	.	.912
		N	60	54
	Cogbooks Activity Hits	Correlation Coefficient	-.015	1.000
		Sig. (2-tailed)	.912	.
		N	54	54

4.1.1 Ease of Use

Ease of use is the first subtheme of student perception, see Figure 4.5. While categorizing ease of use as an enabling constraint may appear contradictory, upon closer examination it is perfectly reasonable. An enabling constraint is that combination of randomness and coherence that enables a user of the system to create something that transcends the limits of the system. Seemingly random actions on behalf of the participant, mediated through perceptions of ease of use, coupled with the coherence provided through the adaptive courseware allowed the participant to create new ways to learn. In this case, how a participant within the system perceived the difficulty of using the system influenced the outcome of the semester—in this case her performance in the course by her activity on individual assignments.

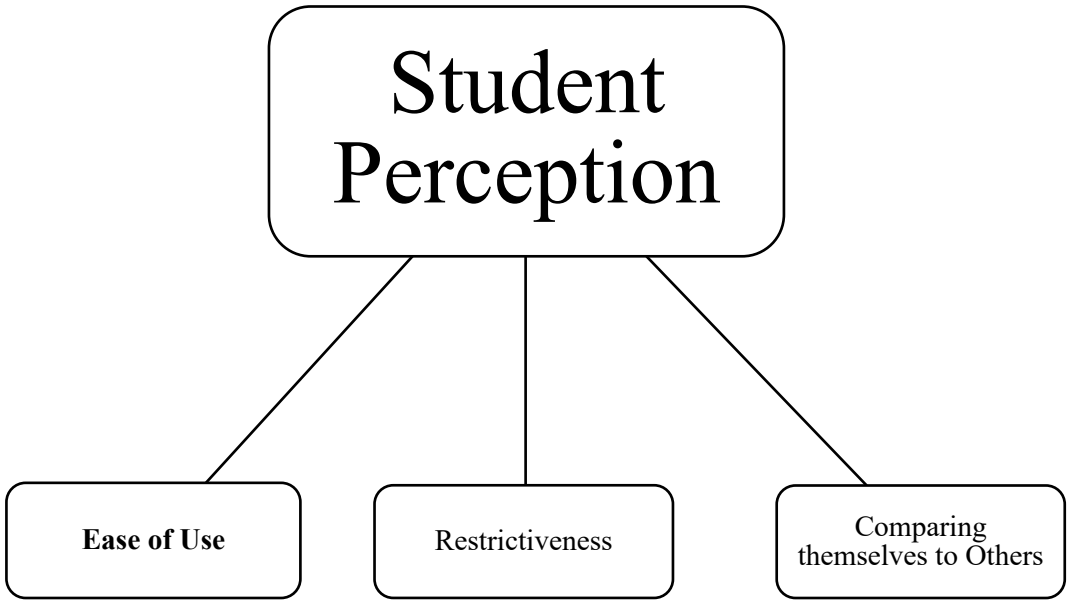

Figure 4.5. Subtheme: Ease of use

There were two questions that directly asked the participant about her perceptions of CogBooks and Blackboard: tell me about your first perceptions of using the CogBooks activities and tell me about your first perceptions of using Blackboard.

For these two questions, 19 of the participants had positive initial perceptions of CogBooks, with two reporting confusion as they began using the system, though they both stated that they quickly became accustomed to it. For the 19 individuals who reported positive perceptions of CogBooks from the beginning, navigation and ease of use were most often stated as the reasons for this positive assessment. In regard to Blackboard, 18 reported positive initial perceptions of the LMS, with ease of use, organization, and communication being the most frequent justifications. Of those 18, however, Sarah did state that she understood why some people new to college might have difficulty with Blackboard, "because it is tricky if you don't know what you are doing with it" (Sarah, personal communication, November 20, 2020). However, only one of the participants beginning her college career corroborated this assertion by reporting her difficulty with the LMS. This participant, Emilia, reported difficulties getting used to the Blackboard at first, but "after a week or two, I got the hang of it" (Emilia, personal communication, November 23, 2020). One other participant, Stella, reported less than favorable perceptions of Blackboard, stating "there's a lot of glitches, so it's not my favorite" (Stella, personal communication, November 27, 2020). Oddly enough, one of the participants who had a positive attitude toward Blackboard's features, Wanda, reported a similar opinion regarding Blackboard's reliability "I just don't like how sometimes it gets shut down and it's like, you can't use Blackboard at all" (Wanda, personal communication, November 21, 2020). Perception toward ease of use, then, is a highly subjective metric that the students weigh with personal preferences.

While these two questions were directly related to ease of use, this theme was evident throughout the data as well, particularly when CogBooks and Blackboard acted as enabling constraints related to student behaviors and ease of use. Participant perception of the ease of use

of the system is an enabling constraint because it provides a metric with which the participant judges how to and when to use the system. This constrains the participants' actions to a behavior predicated upon participant judged relevance, thereby allowing the participant to use the system in innovative ways.

The content in CogBooks is divided into smaller categories, for example in Module 4.3: Transcription, this topic was further subdivided into, Transcription Process in Prokaryotes, Transcription Process in Eukaryotes, and Transcription Elongation and Termination in Eukaryotes, among others. As a result, the participants were able to utilize this to their advantage. Breaking content into smaller categories is a common organizational practice for content providers; in this case, several participants reported using the electronic delivery of the content coupled with its subdivision to facilitate review before exams (Emilia, personal communication, November 23, 2020). Jennifer changed her way of using CogBooks after the first exam "because I took time to read the lectures and take notes from the videos, so I could look at them when I had doubts" (personal communication, November 20, 2020), and on subsequent exams relying on "the text and the critical thinking" [exercises in CogBooks] (Personal communication, November 20, 2020). So, the participants transcend the limitations of CogBooks to prepare for exams in novel ways.

Participants utilized other CogBooks' features so that they received unintended benefits from the system. While many participants argued that the sliding scale within modules with which they could report their understanding could be abused by students who merely wanted to finish a module as quickly as possible, others found novel uses for this feature. This is a clear example of CogBooks as an enabling constraint. One such example comes from Emilia, who discussed using this feature to underreport her understanding so that she could intentionally

receive reinforcement with some concepts (Emilia, personal communication, November 23, 2020). Sarah reported similar behavior with this feature, using it to enforce understanding:

> You have to slide the little do you understand yes or no, like the percentage thing, and I think the little slide thing is really cool because if I happen to slide less than the little overall 80% then I would get the maybe you should try this and I think that's pretty cool so I can fully understand what it is talking about instead of just going straight into it with no anything. (Sarah, personal communication, November 20, 2020)

So, students could use the system in unintended ways to increase their understanding of the material, and subsequently their performance in the class through better performance on individual assignments.

Other participants used the confidence-reporting feature as it was intended in order to increase their understanding of the subject and, subsequently, their performance. Albert reported that he enjoyed this adaptive courseware feature, because it ensured understanding:

> When you don't know that you're 100% that you know the subject, you could put it to the meter or below 60, I believe, and it will let you know. Ok, well if you don't understand this section you can go to read it and then you'll most likely know about it. After you're in the section, and then they'll give you a quiz to do, just to make sure you know (Albert, personal communication, November 23, 2020)

Albert leveraged the ease of use of the LMS to monitor his progress, as well. When discussing Blackboard, Albert stated that, "on Blackboard the feature I found most useful would most likely be checking on your grades and having the tests available on Blackboard" (personal communication, November 23, 2020). Other participants reported similar opinions, using the

adaptive courseware and the LMS's ease of use to both increase their performance in individual modules, while monitoring their overall performance in the course.

4.1.2 Restrictiveness

Restrictiveness is the second subtheme of student perceptions, see Figure 4.6. While there was a question directly related to whether or not the participant viewed the adaptive courseware as restrictive, as a subtheme of perception, restrictiveness pertains to a participant's awareness of how the system limited or liberated their behaviors thereby influencing their performance in the course. How they perceived the parameters of the system as a whole was an enabling constraint in that it allowed the participants to create opportunities for their success within the limits of the system itself. After perceiving limits upon their behaviors, they then transcended these restrictions by constructing new behaviors without these perceived limits.

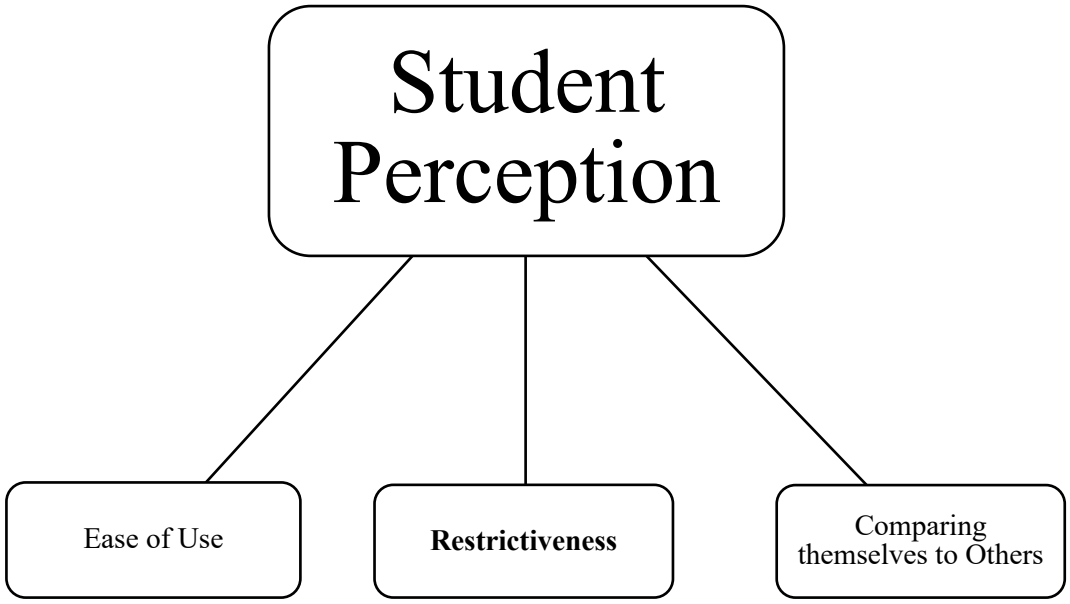

Figure 4.6. Subtheme: Restrictiveness

When asked directly if they found the adaptive courseware (CogBooks) restrictive, most participants replied in the negative. However, in the follow-up interviews restrictiveness as a

theme became prevalent. In these interviews, the participants were asked how they wish the professor had used the adaptive courseware differently and what changes they would like the developers to incorporate into the courseware. In these follow-up interviews, the participants generally stated that the professor had used the courseware as best as could be expected. While she did maintain that the professor needed to include "a little meeting, so she can attract her students, a little bit face to face, because sometimes the students need that" (Daniela, personal communication, December 5, 2020), she also stated "she [the professor] was doing good in the class as a whole, and the organization of the whole class is really good (Daniela, personal communication, December 5, 2020). Another participant expanded upon this, providing a possible improvement, albeit one that would necessitate a change of environment. Olivia felt that the professor was limited by the courseware in conjunction with the online environment stating "I think that she used it about the best she could've but I think in person . . . breaking up people into groups to talk about each section" would have benefited students (personal communication, November 28, 2020). In this case, the limitation was based on perceived lack of communication time due to the delivery modality of the class itself. However, this limitation was not a consequence of the modality at all. The professor could have provided online discussion forums through Blackboard to facilitate group discussions on individual CogBooks' modules. By not providing these forums, the professor created an enabling constraint, which allowed the participants to explore new areas of the system they could leverage in new ways to create similar benefits to forums. This is a prime example of how viewing the entire course, including CogBooks, Blackboard, the professor's content, the professor, and the participant as a single system would benefit the students. By focusing on the limitations and advantages of the various components of the entire system, strategies could be implemented that allowed the participant to

transcend the limitations of one given aspect of the system as a whole, a prime example of an enabling constraint.

Others found the adaptive courseware restrictive because of the nature of the material. Olivia expressed concern about the amounts of different materials within CogBooks, stating that she spent more time within that system in particular because:

> It takes a little bit more effort to get through it and everything because with a video you can just set it down or whatever and with the quizzes you can come back to them because it's just five questions, so I feel that CogBooks as an assignment was a bit bigger than the other ones, so it would take more time. (Olivia, personal communication, November 28)

She felt that this constraint allowed her to succeed in this course. When asked whether or not Blackboard and CogBooks improved her performance in the course, she stated:

> Yeah definitely, I think that being able to understand that this is what I need to get done. I am the type of person that once I know what I need to get done I'm going to get it done. So, once I figured it out, it's just easier for me to get what I need and complete it (Olivia, personal communication, November 28)

Daniela echoed this sentiment when asked about the connection between her performance and usage of both the adaptive courseware and the LMS. Until she got used to the adaptive courseware system, she found the time constraints quite restrictive. However, as has been demonstrated elsewhere, ultimately, this time requirement operated as an enabling constraint, allowing her to transcend this restriction and perform better in the class. "Blackboard and CogBooks affected me by staying on track and staying focused on what was due and how to manage my own time" (Daniela, personal communication, December 5, 2020). The extensive amount of time the adaptive courseware took was actually ameliorated by the LMS.

4.1.3 Comparing Themselves to Others

Comparing themselves to others is the third subtheme of student perception, see Figure 4.7. As will be discussed in depth later, there was a strong element of reflection related to how the participants related their goals to prioritizing relevance of sources. However, within perception, reflection was also related to goals and system usage, albeit related to how participants perceived their peers' usage and performance. Again, this is an enabling constraint because the participants are able to perceive their peers' behaviors with the system in a manner that influences their own behaviors, and subsequently their performance. For example, some participants believed that their peers were just using the system in order to gain the participation points, providing justification for their own lack of genuine engagement with the adaptive courseware activities. Their peers' behaviors provide the randomness to influence their own behaviors in such a way that the system is maintained.

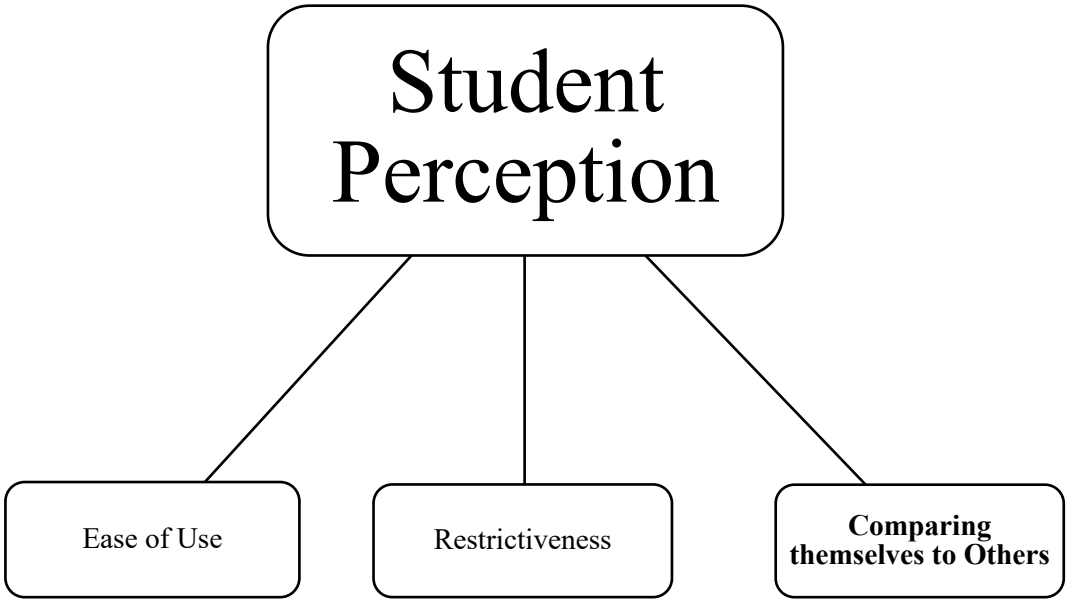

Figure 4.7. Subtheme: Comparing themselves to others

For the participants, there was some disconnect between how they perceived their own behaviors in connection with their goals compared to how they viewed their peer's behaviors. One interview question was directly related to this issue: How do you think your usage of CogBooks compares to your peers?

As will be demonstrated later, participants viewed their behaviors directly in accordance with their goals, although this did not withstand analysis. In addition, most participants assumed that their peers viewed the adaptive courseware similarly to how they viewed it. For Gabriela, the other participants "just want to get through it" because the participation points given for completion of the CogBooks' activities are "the easiest thing you can do to pass" and it did not "really matter if you did it correctly," because the exams were more related "to her [the professor's] slides and lectures than to CogBooks" (personal communication, November 18, 2020). Emilia stated a similar belief, saying, "Some probably use it differently because the thing about CogBooks is you could just skip all of them. I feel that that is probably a negative because we get graded on this too, and I guess some people who are lazy might just skip through all of it" (personal communication, November 23, 2020). This assumption is directly related to Gabriela and Emilia's own assumptions about their usage of CogBooks. For others, including Jessica, her peers' behaviors would be different from hers. At first, she stated that most students were just doing enough in CogBooks to pass the course because everyone's goal "is just to pass the class in general (Jessica, personal communication, November 23, 2020). After some reconsideration, though, she stated that her peers' behaviors would be in line with their individual goals, with some participants wanting to "learn it as well" (Jessica, personal communication, November 23, 2020) but for individuals with unrelated majors "probably just, like, getting by" (Jessica, personal communication, November 23, 2020). The coherence between Jessica's behaviors and

those she perceives as similar to herself provides the opportunity for her to interact with the system in such a way as to ensure its continued existence.

Other participants assumed that their own behaviors would be similar to others', taking into account individual differences. When asked to compare her behaviors to others, Andrea stated, "I would say overall they used it the same, but of course every student is different. Some may have needed more resources and some may have needed a little less" (personal communication, November 20, 2020). In this case, it appears that Andrea based her determination on the other participants' resource needs rather than directly to their learning goals. However, as demonstrated elsewhere in the study, resources and learning are directly related. In terms of the CLE, resources are part of content and goals are one of the components that make up the learner's complex system of behaviors.

4.2 RELEVANCE

Relevance is a complex theme because it relates to how the students navigated the system, prioritized usefulness, and used the system to reach their goals. For this study, relevance is categorized as specialization—a combination of the internal diversity and internal redundancy necessary to ensure the propagation of the system. See Figure 4.8 for a graphic depiction of relevance as theme and as the dyad specialization.

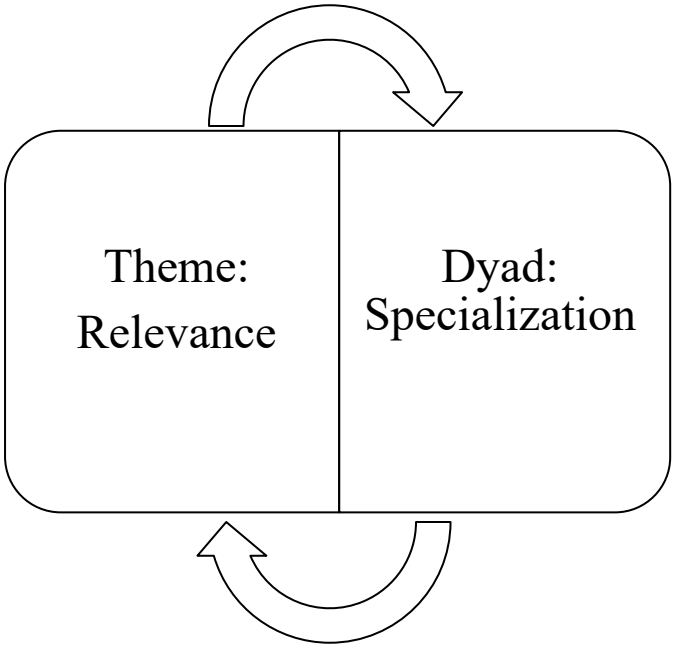

Figure 4.8. The Relationship between Relevance as a Theme and as a Dyad

In this case, the system is not merely the adaptive courseware, but the CLE. As demonstrated in Figure 4.1, the adaptive courseware and the LMS can be depicted as a location, technology and digital instructional materials. Within this theme, three subthemes have been identified—navigating the system, prioritizing usefulness, and navigating the system, see Figure 4.9.

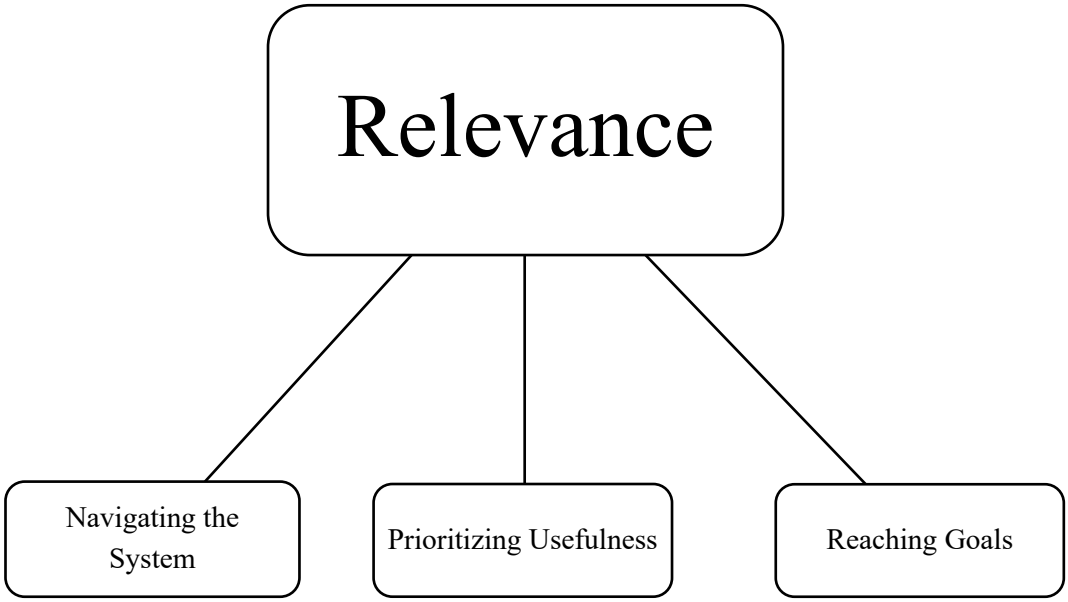

Figure 4.9. Relevance Subthemes

The quantitative data demonstrating the relationship between student behavior, as indicated by LMS content hits and student performance on an individual assignment, in this case Exam 4, is included with this theme because it relates to the relevance that students placed on using the LMS. In this case, LMS access is being used to indicate relevance in that participants would most likely utilize sources that were most relevant to an immediate goal, in this case passing Exam 4, one of the major exams given during the course. It covered material within the adaptive courseware but also concepts and terms discussed in the professor provided resources. The variable, LMS Content Hits, represents the number of times that students clicked on content links in the LMS. These links include links to the professor-provided resources as well as the adaptive courseware. The relationship between these two variables illuminates the process in which relevance mediated system usage, and as depicted in Table 4, there was shown to be a significant relationship between the number of LMS content hits during this time and their score on Exam 4, $r_s = .347$, $p = .008$.

Table 4: Correlation between Exam 4 and LMS Content Hits

			Exam 4	LMS Content Hits
Spearman's rho	Exam 4	Correlation Coefficient	1.000	.347**
		Sig. (2-tailed)	.	.008
		N	58	58
	LMS Content Hits	Correlation Coefficient	.347**	1.000
		Sig. (2-tailed)	.008	.
		N	58	60

**. Correlation is significant at the 0.01 level (2-tailed).

Similarly, the correlation between students' interaction with the adaptive courseware measured through their confidence level with its content and their performance on a specific course exam taken during the data collection window relates to this theme, because it demonstrates the complexity of student/system interactions. CogBooks Confidence Level measures how well the participants felt they had grasped a given concept. While confidence level could be mapped to perception, it is mapped to this theme because of its relationship to the dependent variable. Taken as a whole, this relationship is related to relevance in relation to specific assignments. From the data listed in Table 5, one can see that there was no significant relationship between the participants' confidence level with the adaptive courseware content during this time and their score on Exam 4, $r_s = .122$, $p = .379$.

Table 5: Correlation between Exam 4 and CogBooks Confidence Level

			Exam 4	Cogbooks Confidence Level
Spearman's rho	Exam 4	Correlation Coefficient	1.000	.122
		Sig. (2-tailed)	.	.379
		N	58	54
	Cogbooks Confidence Level	Correlation Coefficient	.122	1.000
		Sig. (2-tailed)	.379	.
		N	54	54

4.2.1 Navigating the System

How the students navigate the entire system—including the content, the technology, and interaction with the professor—is a key component of relevance, see Figure 4.10. The students use metacognition to correlate the relevance of the resources to the navigation of the tools that deliver the resources. In this case, it is also representative of specialization, because this behavior helps propagate the system. As the students weigh relevance and navigation this creates a system that is responsive to and indicative of the students individual learning needs, thereby influencing student performance, while simultaneously creating the system customized for the participants' individual priorities.

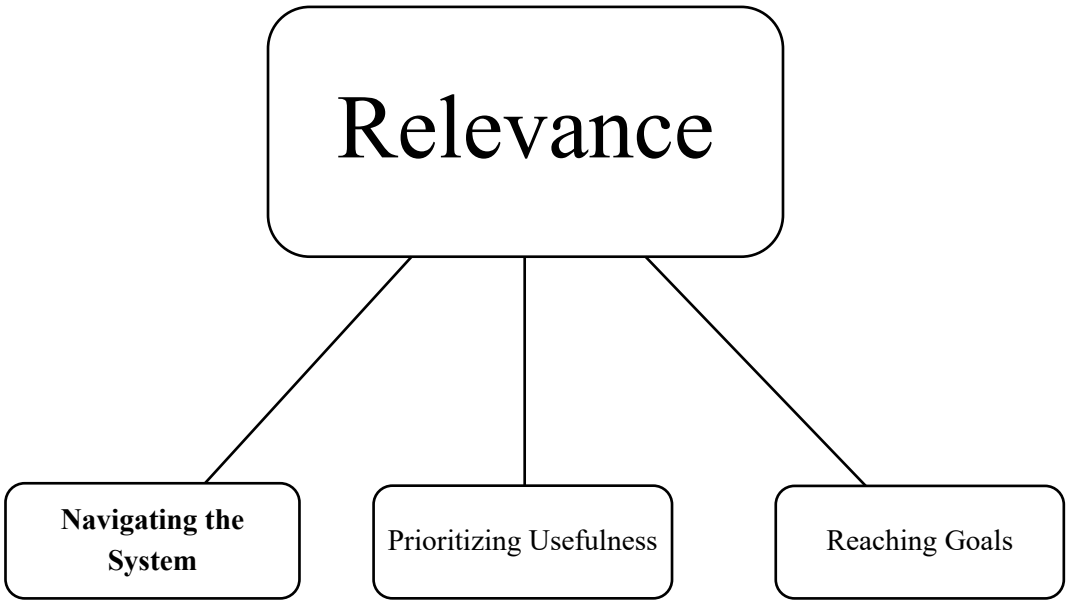

Figure 4.10. Subtheme: Navigating the System

This instance of relevance emphasizes the modality of resource delivery rather than the resource itself. Again, this is demonstrated through Figure 4.1, which illustrates how the LMS operates simultaneously as location, technology, and content. In this case, the resources were either delivered through the adaptive courseware or through the LMS—including all the non-

adaptive courseware resources. This theme is related to the next subtheme, in that the participant helps propagate the system as a whole by determining the relevance of a given technology related to the participants' needs. It differs in certain respects, though, because it is not a case of creating a personalized system based on usefulness, which the data will demonstrate later.

Rather, it is an example of creating a system that illuminates the individual learning needs mediated through delivery method. For example, when discussing her confidence with biology, Sarah admitted that at times she was anxious about some of the content, "I was trying to do an assignment and was a little bit scared from looking at it because it was stuff I didn't really know" (Sara, personal communication, November 20, 2020). In this part of the interview her recount of this particular event evokes her remembered anxiety. She was unsure of what type of resource to even use to address this knowledge deficit— "I didn't really know. I guess the resources to go find" (Sarah, personal communication, November 20, 2020) the answer to her problem. Once she was introduced to CogBooks, though, she had a resource that ameliorated future anxiety related resource identification, "when CogBooks was introduced it was really easy to use and it wasn't intimidating to go through" (Sarah, personal communication, November 20, 2020). While Sarah found the content useful, it was the ease of CogBooks that actually made the system more relevant for her. She was able to navigate the two nodes of content and technology by utilizing a technology that met her learning needs, in this case, relieving the anxiety the content was causing. The participant's individual learning system is created through her process of navigation as it is mediated by relevance.

In Sarah's case, anxiety with new content was a key component of her learning needs. The data demonstrated several other methods by which participants identified their individual learning needs, though. In the context of complexity studies, "learning is a process of emergence

and co-evolution of the social group and the wider society. Emphasis is place on the *relationship* between elements rather than the elements themselves" (Morrison, 2008, p. 451). This definition of learning is evident in this theme. For the participants, they had to mediate their own learning needs through navigating the system in a manner that optimized performance based on those needs. It is the relationship between nodes in the system that creates this emergence. For Sarah, learning needs meant retaining information. She navigated all of the materials provided in the course, both CogBooks and professor-provided materials, in a way that she felt the material "builds upon it[self] and builds upon the stuff you are already learning and in general that helps me get a better understanding of what I'm supposed to be retaining" (Sarah, personal communication, (November 20, 2020).

Once they had identified their learning needs, the participants could navigate the system. In this case, they were navigating the actual delivery tool. The participants navigated the system as a whole—content, technology, and instructor—based upon their individual learning needs. In general, these needs can be categorized as situations in which the participant needed to study content in depth because of lack of familiarity, or situations where the participant could skim though information because they were already comfortable with it. For example, when faced with information that he felt he was already strong with, Albert relied on CogBooks, "if you already know it, just skim through" (personal communication, November 23, 2020). The convenience of the delivery modality was a key component in his choice. For this student, the convenience made his choice easy, "CogBooks was always there for me when I needed to learn the most (Albert, personal communication, November 23, 2020). For Andrea, convenience manifested itself through the ease of using CogBooks:

> The resources that the professor had were all in different links. There were tabs and I wouldn't say it was all over the place. It was just a lot more clicking and with CogBooks everything was on the same page. (Andrea, personal communication, November 23, 2020)

The participants were able to create opportunities to meet their learning needs with the delivery method that best fit those needs, given the constraints of the system as a whole. A key limitation in this system, was the fact that everything was delivered online. The participants were able to turn this limitation into a component of specialization when they propagated the system through their choices mediated by relevance. They navigated the system not through the limitations of the technological tools, rather through their individual needs.

4.2.2 Prioritizing Usefulness

Prioritizing usefulness is the second subtheme of relevance, see Figure 4.11. This subtheme examines how participants equated the usefulness of a given source to its overall relevance to their use of the system. As with the other subthemes of relevance, prioritizing usefulness is an instance of specialization because it relates to the propagation of the system. As the students employed their own definition of useful, sometimes pertaining to learning and sometimes to grades, they were able to prioritize the wide variety of sources available in order to create their personalized system.

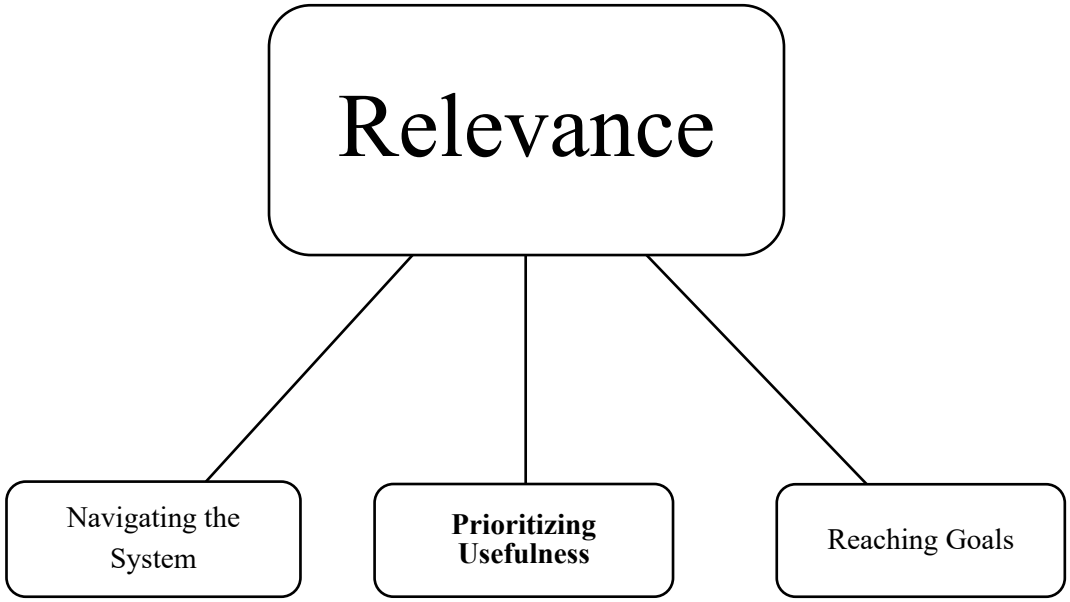

Figure 4.11. Subtheme: Prioritizing usefulness

As discussed earlier, this course provided a variety of resources. CogBooks included readings, videos, and interactive activities. The professor provided other resources including YouTube videos, recorded lectures, PowerPoint presentations corresponding to the lectures, and optional activities. These varied resources were available for each module. This variety of resources in each module necessitated that the participants navigate the entire system in relation to relevance, because using all resources in the same way would not allow them to utilize the resources to their potential.

In order to navigate this complex combination of resources, the students mediated their usage of resources through metacognition related to relevance in order to create a system of their very own. When discussing the usefulness of CogBooks in helping her learn the content, Sandra was quick to depict the interconnection of the sources in her own usage:

> It gives you extra information because I guess from the mini lectures that the professor put for us and stuff like that you get an idea of what CogBooks are gonna be about so you

can get into that mentality into your mind so when you get reading and everything is put in place and makes sense. (personal communication, November 19, 2020)

The metacognitive processes the participants expended on relevance, by prioritizing usefulness, are also evident even when participants found the activities difficult. When discussing the features, she found most useful, Samantha mentioned that she found the matching activities in CogBooks useful even though she thought the definitions made the activity "somewhat tricky," (personal communication, November 25, 2020). She also mentioned that the quizzes "were also tricky" (Samantha, personal communication, November 25, 2020), but, ultimately, she found both "very useful" (Samantha, personal communication, November 25, 2020), given that they both helped her "remember what I had read" (Samantha, personal communication, November 25, 2020).

Both of these participants' usage of the adaptive courseware demonstrates their thinking related to the resources and their interconnections, thereby maximizing individual learning opportunities. As demonstrated in Figure 4.1, the participants view the resources as both related to and separate from a particular delivery system depending on a particular situation.

This metacognition allowed the students to exercise both ontological and epistemological agency, in which they created their own reality where they chose what to learn in accordance with their current needs. As she discussed how CogBooks, the professor's resources, and Blackboard worked together, Anne related a rather complex interaction where she created a reality based on how she learned:

I guess CogBooks was able to help you do this because I would go to CogBooks and then I'd understand. I'd go over like the material. And then I would go to Blackboard and then she [the professor] would include the lectures and I'd be taking more notes on that, and

then go over it with the activities to make sure that I understood it." (Anne, personal communication, November 24, 2020)

This internal redundancy of resources is a prime example of specialization, which ensures the propagation of the system. Anne has created a complex experience where the individual resources work together to generate a learning environment all her own.

Once they have created a reality that meets their learning needs, they can create the knowledge instances that determine the scope of what they learn. When discussing how she made her decisions about which resources to use, Gabriela immediately made distinctions about what to learn and why to learn it. For tests she concentrated on "her slides and the lectures, because that is pretty much what she is basing it [the test] off of" (personal communication, November 18, 2020). For her, CogBooks was "extra information because sometimes you do need that background" (Gabriela, personal communication, November 18, 2020). Gabriela has prioritized her information needs according to use. For merely passing the test, a reliance on the professor's lectures was sufficient. When a more complete understanding of a given topic was required, she would rely on CogBooks. By exercising this ontological and epistemological agency mediated by relevance, the participants have created a system of their own design.

4.2.3 Reaching Goals

The third subtheme of relevance is reaching goals, see Figure 4.12. This subtheme is closely related to prioritizing usefulness because the personalized system the students created was subsequently used to achieve their goals. This subtheme is also indicative of specialization because it ensured the propagation of the system itself. The participant's identified the source they thought was most useful as it related to their particular goal in class and then concentrated on that source. This determination of resource usefulness through goal relevance mediation was a

complex process that relied on the participants' ability to propagate a system that met individual needs with the resource that best met those needs.

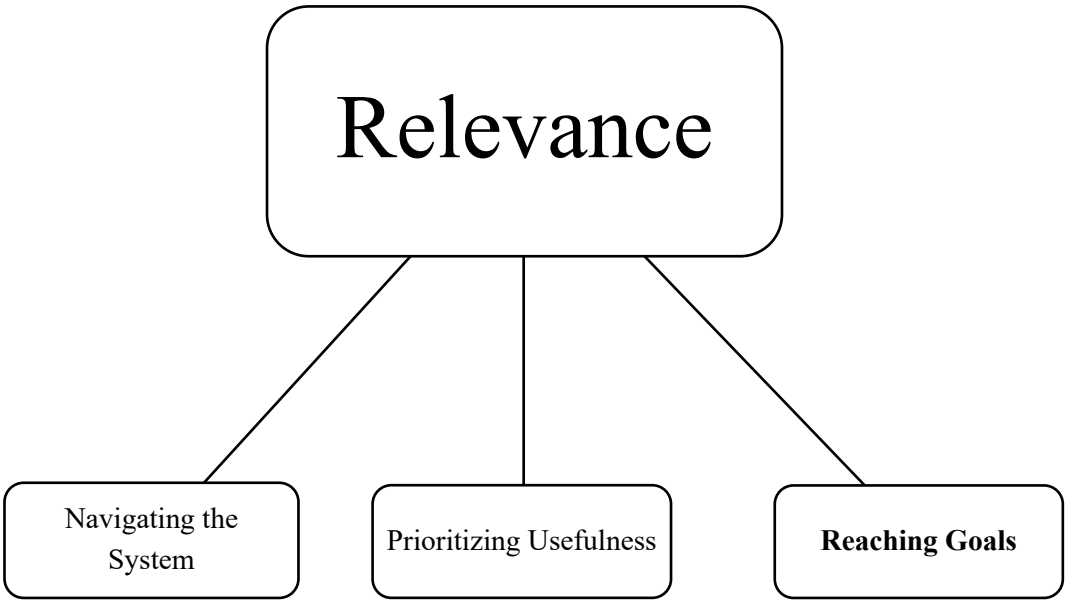

Figure 4.12. Subtheme: Reaching Goals

While the subthemes related to relevance and personalization of the system in various ways, this subtheme deals specifically with prioritizing goals as the mediator. The participants each had three types of goals, as demonstrated earlier. For long-term goals, all 21 of the participants reported pursuing long-term goals that required passing this biology course. One of the participants stated that she wanted to be a high school biology teacher, with the other 20 pursuing careers in the medical field. For short-term goals all 21 reported that their goal for the class was to learn the required material to build a strong foundation for future learning or to pass the class. Participants were not asked directly about immediate goals. However, given that the participants all wanted to pass the class, the researcher extrapolated from that desire to determine that immediate goals included successfully navigating each individual module.

This examination of the evidence will begin with an examination of long-term goals in relation to resource choice. Given that all of the participants had long-term goals that required a strong foundation in biology, one might assume that they would all choose similar resources. However, this is not what the data indicates. Instead, the participants chose resources that they felt would most benefit their acquisition of the requisite background knowledge. While some participants chose CogBooks resources, others chose professor-provided resources. The mitigating factor was personal choice based on their relevance metrics. For example, Emma's discussion of resource choice is very clear:

> It [CogBooks] was very structured in the sense that there was one topic and there were three paragraphs on that one topic and then a video. Instead of some of her mini lectures or her PowerPoints they're very broad, so it'll be like oh this is the topic, and then they'll start talking about something and then they'll be like, oh, but this ties back into this from the beginning and so not that they're not structured but that they, they jump around a little bit, because they need too, where CogBooks has everything consolidated into one. (Emma, personal communication, November 21, 2020)

In this example, one can clearly see that the participant's choice to use CogBooks was made because this resource provided her with the best chance to learn the material, due to how she perceived the module's focus.

However, other participants made different decisions using the same justification. Antonio discussed his experiences in class, and how he navigated the disparate components of the system. When asked about CogBooks as a replacement for a FTF environment, he quickly segued into a discussion of the system as a whole. While he did value the usefulness of CogBooks, he stated, "the reason I'm doing really good in this course is more because of our

professor" (Antonio, personal communication, November 25, 2020). He credited her "videos that explain the notes at a greater depth" as a key component of why he valued these resources. Although Sandra did not specifically mention the professor's direct role in her success, she did state that the professor's PowerPoint presentations were the most important "because for all the quizzes all the answers are there. You have to read obviously but the answers are there. You don't have to read all these paragraphs. They are just short and clear and the answers are there" (personal communication, November 19, 2020). These resources met the participants' learning needs better than other resources. In Antonio's case, this participant chose the instructor's resources as the best choice possible to acquire the necessary foundational knowledge in biology. For Sandra, these same resources were the optimal choice because of their conciseness and relevance to the tests. This demonstrates how individual relevance is a personal choice that allows the participant to create and maintain a system that best fits their long-term goals.

Given that immediate learning needs are directly related to short-term goals, this analysis will examine how students pursued both of these goal types through resource choice simultaneously. As demonstrated previously, participants used the same justification for their resource choice while choosing different resources. As Gilbert discussed how he prepared for tests, he related how CogBooks was essential to his preparation, "I'd go back and read the sections and see if it could help me fill in the blanks" (personal communication, December 1, 2020), although he was also careful to point out the professor's contribution, "But she gave us an overview about the topic for the exam" (personal communication, December 1, 2020). In this case, the participant identified CogBooks as the best route to success in the module and ultimately in the course itself because while the professor explained things, "CogBooks did go over them more deeply" (personal communication, December 1, 2020). Other participants used

the same reason to choose other resources. When discussing her reliance on the professor's resources, Kari mentioned that she found those resources more inline with the tested content itself, "I've seen it from testing experience, and sometimes things that they [the professor] mentioned they put it directly in the exams. So, having a good grasp of those resources that she herself included would help me out with quizzes" (personal communication, November 24, 2020). In this instance, the participant found that the instructor's resources better met what she would need to know to pass the course.

4.3 LOCATION

Location is a difficult theme to define. It does not represent the physical location of the student as they took the course online. Nor does it depict the theoretical location of the learner on the didactical tetrahedron, given that the particular node on which the learner is placed does not change the overall function of the tetrahedron. Rather, by location this study refers to the relative distance with which the participant situates themselves in alignment with a given resource. For this analysis, location is associated with the trans-level learning dyad—the connections between nodes that create the system and decentralization of control, see Figure 4.13. This decentralization provides opportunities for the learner to control her own learning by locating herself closest to the technology and content resources that best facilitate her learning.

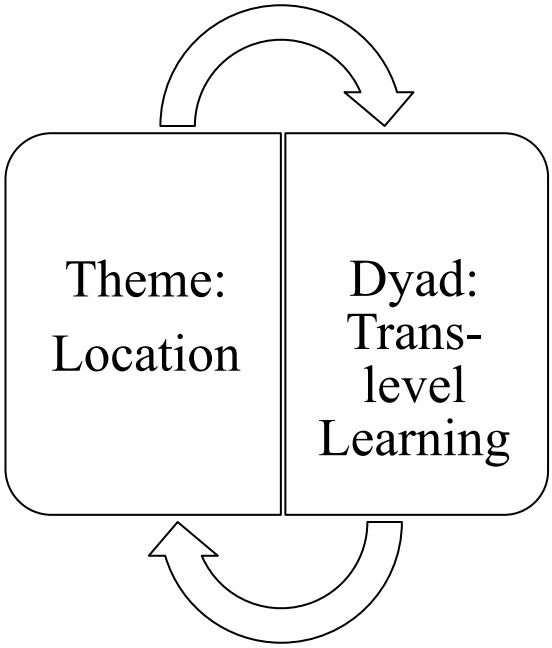

Figure 4.13. The Relationship between Location as a Theme and as a Dyad

Related to the theme of location, the quantitative data related to the relationship between student performance on a specific assignment and the time she spent using the adaptive courseware is included here because it is indicative of the complex space that the users create for themselves through the use of the CLE as a whole. In this case, the relationship between the time spent specifically on adaptive courseware activities and Exam 4, which included content delivered through the adaptive courseware and the professor's sources.

Throughout the course, the students had several exams that covered concepts taught through the adaptive courseware and the professor's resources, including recorded mini-lectures, presentation slides that followed the mini-lectures, YouTube videos, and optional exercises. During the quantitative data collection window, from November 27 to December 12, Exam 4 was the major assessment. As seen in Table 6, there was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their score on Exam 4, $r_s = .298$, $p = .028$.

Table 6: Correlation between Exam 4 and CogBooks Total Time

			Exam 4	Cogbooks Total Time
Spearman's rho	Exam 4	Correlation Coefficient	1.000	.298*
		Sig. (2-tailed)	.	.028
		N	58	54
	Cogbooks Total Time	Correlation Coefficient	.298*	1.000
		Sig. (2-tailed)	.028	.
		N	54	54

*. Correlation is significant at the 0.05 level (2-tailed).

Another indicator of the complex space that students created for themselves as they navigated the complex education system is the correlation between the total time a student spent using the adaptive courseware during the data collection window and the average score on the adaptive courseware assignments completed during the same window. This relationship provides another dimension to the previous data, because in this case the score represents student grasp of materials solely delivered through the adaptive courseware. Along with major exams delivered through the LMS, the adaptive courseware had built-in assessments. The variable CogBooks Average Score represents the average score of these assignments during the quantitative collection window. There was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their total score on adaptive courseware assignments, $r_s = .398$, $p = .004$, see Table 7.

Table 7: Correlation between CogBooks Total Time and CogBooks Average Score

			Cogbooks Total Time	Cogbooks Average Score
Spearman's rho	Cogbooks Total Time	Correlation Coefficient	1.000	.398**
		Sig. (2-tailed)	.	.004
		N	54	50
	Cogbooks Average Score	Correlation Coefficient	.398**	1.000
		Sig. (2-tailed)	.004	.
		N	50	51

**. Correlation is significant at the 0.01 level (2-tailed).

This theme is divided into three subthemes—how participants used resources, how they created a learning space for themselves within the system, and how they viewed themselves as learners, see Figure 4.14.

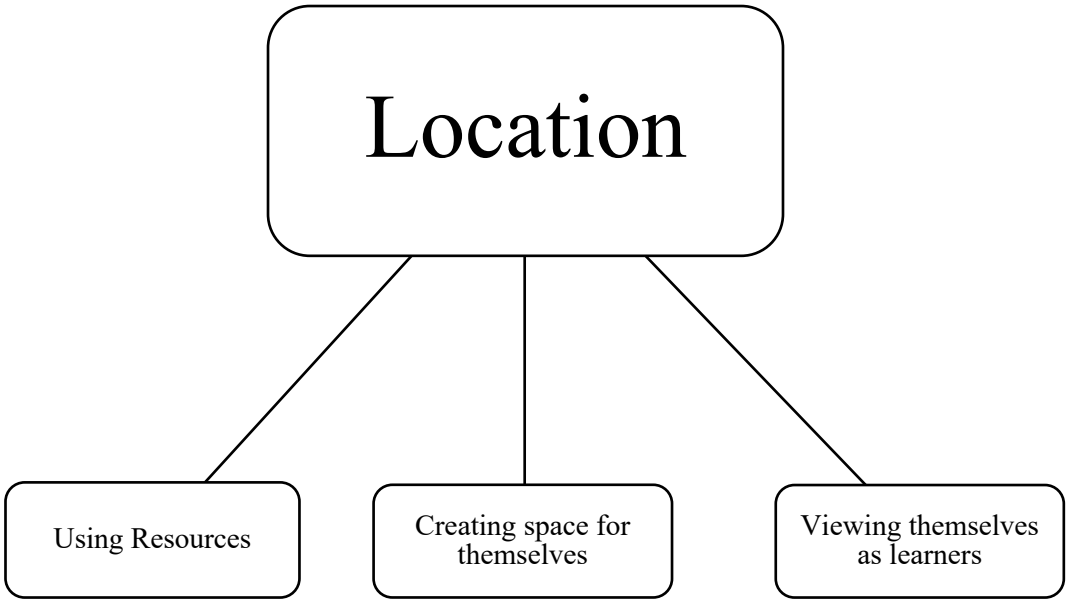

Figure 4.14. Location Subthemes

4.3.1 Using Resources

Using resources is the first subtheme of the theme location, as depicted in Figure 4.15. As previously discussed, content is a central node along the didactical triangle. This subtheme is an example of trans-level learning, like the others in the theme of location, because it is indicative of how students were able to engage in both centralized and decentralized learning. In this course, the content included a variety of sources, all of which were delivered digitally. These resources included CogBooks, the adaptive courseware in question, which in turn included a variety of sources such as videos, readings, quizzes, and matching exercises; and professor-provided content, such as PowerPoint presentations given as recorded mini-lectures, YouTube videos, and optional exercises. Again, as depicted in Figure 4.1, the content is both related to and

separate from the individual system, the LMS or the adaptive courseware. The participants were able to locate themselves in relation to these given resources in such a way that they leveraged their learning preferences manifested through their behaviors to positively influence their performance in the course.

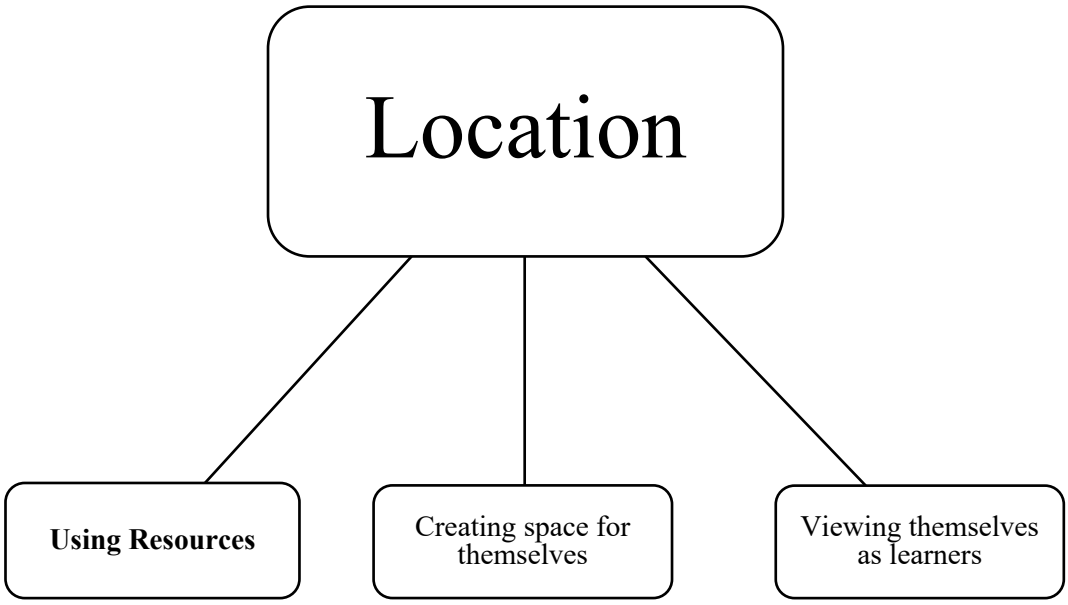

Figure 4.15. Subtheme: Using Resources

As the participants navigated the course, they were presented with a wide variety of sources. This selection of resources provided for instances of trans-level learning, where connections between particular nodes were strengthened and teaching control was decentralized. While the adaptive courseware activities were mandatory, there were others that were not. All of the participants stated that a major reason for completing the CogBooks activities were the 30 points they received for that assignment. The participants realized that completing these activities was essential to receive a good grade. When asked why she used CogBooks, Olivia said, “It was easy to get those participating grades because you were also able to learn in the process, so it’s not that you were just doing it to get it over with . . . And once you get it done,

it's like ok this was an easy grade" (personal communication, November 19, 2020). Although this rationale positions CogBooks as an essential resource for completion of the course, the data also demonstrates that participants realized they could also learn from CogBooks as they were getting their participation grade. Andrea extolled the variety of resources in CogBooks as being essential to her learning, "it has videos and it has pictures and different links and different mini-subject in the bigger subjects to it is easier to access what you want to look for and easy to understand" (Andrea, personal communication, November 20, 2020). So, as she used CogBooks to earn the participation grade, the variety of sources provided her with varied methods to learn.

Other reasons for using particular resources are classified here as learning preferences, because they are indicative of particular proclivities individual participants possessed. In this study, learning preferences are the inclinations that the participants had toward a given resource based upon their particular predispositions. One of the preferences was whether or not the participant liked to read. Several participants stated that the amount of reading in CogBooks was a barrier to use. As she discussed her usage, Jennifer bemoaned getting lost in the amount of reading, "It helped but also if the topic was too long, I got lost. I got lost and would have to read all over again" (personal communication, November 20, 2020). So, it would seem to follow that participants who were disinclined to read would use CogBooks less than those who liked to read. In his discussion of using CogBooks, Antonio admitted that the amount of time was a barrier to a careful reading of all the CogBooks resources, "It definitely doesn't take into account all the time you spent on it and stuff" (personal communication, November 25, 2020), though he did admit that "It was very useful. Personally, like for me it was more interesting and useful just to learn those things" (Antonio, personal communication, November 25, 2020). Unfortunately, there is no quantitative metric available through either the adaptive courseware system or the LMS that

would facilitate an analysis of this apparent correlation. Nor, were there any specific questions in the qualitative data directly tied to this phenomenon. By locating themselves in relation to a particular resource, the participants were able to exercise control of their experiences, a key component of trans-level learning.

However, the qualitative analysis did provide additional insight on the relationship between individual learning needs and resource choice. An apparent mitigating factor was time constraints. Participants reported that their choice of resources—either CogBooks or professor-provided material—was predicated upon the amount of time they had to spend on a given module. When asked about her usage, Hannah stated that "there were times when I would just scan through it and leave it, because I work two jobs and I'm a full-time student so sometimes I wouldn't have time" (personal communication, November 27, 2020). However, the choice of resource use mediated by time constraints was not a constant in the data. There were participants who reported a shortage of time who chose CogBooks. Although Daniela also stated that she was often short of time, she relied on CogBooks because "I felt that it was more focused, more straightforward" (Daniela, personal communication, December 5, 2020). This sentiment was echoed by Sarah who commented her own shortage of time before remarking:

> I wanted to do it [CogBooks] to get it out of the way, but once I realized how easy it was to go through CogBooks and how easy it was to understand what was being tough, it quickly became an automatic resource. (personal communication, November 20, 2020)

So, for these participants, the organization of resources allows the participants to exercise more control over their learning.

There were also participants who described a lack of adequate time to devote to the course who chose to rely on the professor provided resources. Although this could be categorized

as an enabling constraint, this instance is actually a case of trans-level learning. As demonstrated earlier, an enabling constraint leads to novel utilizations of the system. In this case however, the time constraint is actually representative of trans-level learning in that the participant uses the lack of time to decentralize her learning opportunities.

For example, Valerie made it clear that time constraints and the overwhelming scope of the information influenced her choice, “The readings were way too long and way too broad and that is what made it not as useful for me. The professor’s lectures were always straight to the point” (personal communication, November 28, 2020). So, a stated time deficiency was not a predictor of resource choice as indicated through the qualitative data. Indeed, one student who consistently mentioned issues with time constraints as a motivating factor in her choices given that she worked a full-time job and went to school full time stated “To tell you the truth, I don’t have time to read anything . . . CogBooks was not useful because I didn’t have time” (Julia, personal communication, December 8, 2020). She found CogBooks no different from a book. “Since I had a job, I had to use my time efficiently and use other resources” (Julia, personal communication, December 8, 2020). However, these resources did not include the professor’s resources either. She found her own resources online, stating that Khan Academy was the most useful resource she used during this course. Relegated to using her phone often at work because of job restrictions, she had to use other resources that she did have access to. One might assume that finding resources other than those provided through the adaptive courseware or the LMS would be more time consuming than using material that one would have to search for oneself, but this would neglect the reality that this student had created for herself where her preferences and restrictions mediated her research choice.

4.3.2 Creating Space for Themselves

Creating space for themselves is the second subtheme of location, see Figure 4.16. Although it would appear that participant location is fixed within the confines of the didactical tetrahedron or the expansion of this model into the CLE, as illustrated in Figure 4.1, complexity theory is able to delve deeper than this superficial view to illustrate the intricacy of the participants' location. While the graphic representations that this analysis has used to illustrate the perceived parameters of the system locate the learner along with the three other nodes, including the content, the teacher, and the technology, the learner is actually afforded more agency than one would assume. As the data will demonstrate, the participants in this study were able to leverage the content and technology to create for themselves a virtual learning space. This learning space provided the students with a location where they could choose resources that met their personalized learning needs, experimenting with the decentralization of control of learning opportunities.

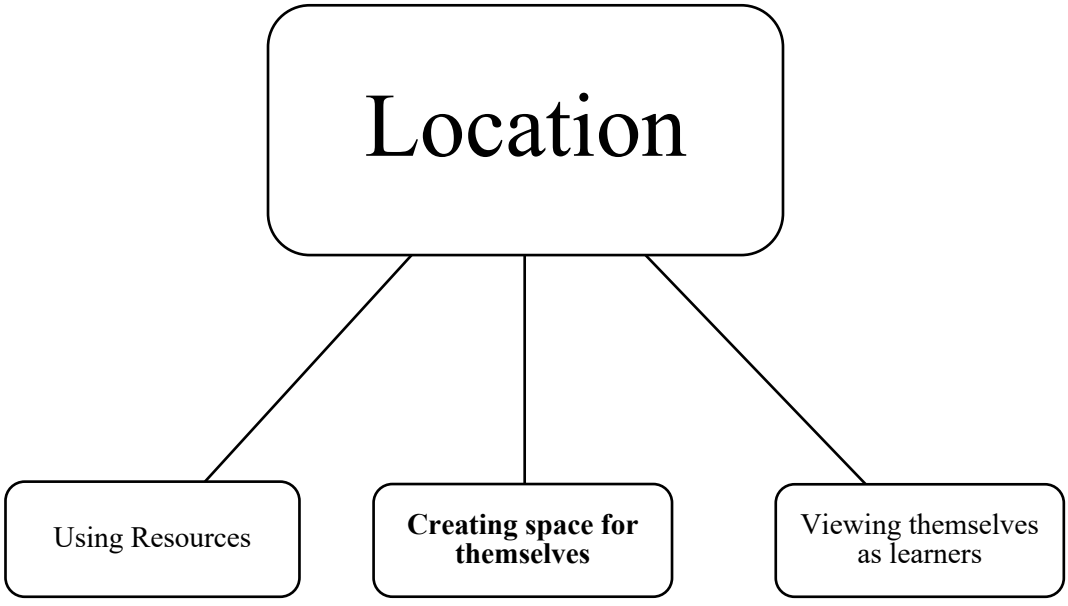

Figure 4.16. Subtheme: Creating Space for Themselves

Though this subtheme is similar to the previous one, there are important differences that help this analysis provide a more thorough depiction of the complex system created by the learner, the instructor, the technology, and the content in this course. While the previous subtheme dealt with how participants used resources in relation to their learning preferences, this one explores how resource and technology use in tandem allowed the participants to create their virtual learning space. This learning space is a prime example of trans-level learning because the interactions between the nodes allowed the participant to exercise various levels of control over their own meaning making experiences.

It is this interconnection of resource type and technology that provided a flexible space in which the participant fashioned their custom environment, a key example of why the LMS and the adaptive courseware are deconstructed into their constituent parts—technologies, resources, and specific locations as part of the CLE model. As depicted in Figure 4.1, the technology and content are facets of both the LMS and the adaptive courseware. The creation of this flexible space is evident throughout the data. As Daniela stated, "At the beginning of the semester I tried to use the other resources that the professor offered, and I found CogBooks more useful due to the fact that I can study more like I have the resource there, and I'm going to study my notes" (personal communication, December 5, 2020). As Emma discussed her preparation for tests, she also relied on CogBooks, "I went through my [CogBooks] notes again. I went through the quizzes because some of those questions were similar to questions on the test" (Emma, personal communication, November 21, 2020). While it is true that particular resources in this course were intrinsically linked to a given technology, students still sought to separate the content from the technology to better suit their learning needs. It can be difficult to extricate the materials provided through CogBooks from the delivery system itself, yet students still were able to do

this. For example, the readings, quiz questions, and videos are part of CogBooks itself. However, even then students would take notes from these CogBooks resources so they could use the information disconnected from the technology.

The entire milieu created by the content and the technology proved surprisingly flexible for the participants. In this course the participants were able to navigate a given module while emphasizing diverse content and technology at different times. When asked whether her usage of CogBooks changed after the first exam, Emilia stated:

> Honestly, yeah, because I found that there were a lot of details that weren't on the test that were in CogBooks and the professor would mention in her mini lectures that some things might not be on the quiz, so those kinds of things you just skim over. (personal communication, November 21, 2020)

When elaborating on this, this participant stated, "I just go into CogBooks as like a checklist to see if I got everything that the professor possibly missed or just small details about a topic (Emilia, personal communication, November 21, 2020). While differing from Emilia in practice, Albert also used the environment created by the content and technology in novel ways:

> While having the mini lecture on, I would also have like half the screen to watch, because I have two monitors as well. So I have another screen, which is like you know if it's very easy when you have to monitors. I would have the other screen on the PowerPoint, and I would look through her lecture video while looking at the PowerPoints as well, taking notes on the PowerPoints while listening to her. And then after doing both of those simultaneously, I would then go to CogBooks and redo that and save some more notes. Apparently parallel to what I did with the professor's resources and kind of just you

know like match them together so that I get a full understanding of what I'm learning. (Albert, personal communication, November 23, 2020)

So, as a system that includes the content, the technology, and the professor, students were able to combine them in unique ways to create a personalized learning space.

Some participants utilized resources and technology to create a personalized learning space in other ways. One common technique was relying on mobile devices to deliver content whenever the chance arose. When discussing the flexibility of CogBooks, Albert stated, "It's very flexible. I would say because you can use it anywhere. You can use it like on your laptop. You can use it on your tablet. You can use it on any device, sometimes on device like phones and everything" (personal communication, November 23, 2020). In this case, the participant was able to utilize the flexibility of CogBooks delivered through a mobile device to provide content when he needed, although he had previously stated that CogBooks was not her first choice of resources. This is a clear example of the relationship between the courseware, as a location, simultaneously functioning as technology and content.

Other participants reported similar patterns. Anne stated that she found the professor's videos the most useful because of the "sense of one-on-one, even though you're not able to like speak to her. You're able to hear what she has to say about the material" (personal communication, November 24, 2020), but she relied on CogBooks more as the semester progressed because of depth of content coverage. This clearly demonstrates that technology and resource choice were not static domains. Rather, they were part of a dynamic process of choosing the appropriate combination of resources and technology to respond to a particular situation.

4.3.3 Viewing Themselves as Learners

Viewing themselves as learners is the third subtheme of location, see Figure 4.17. As previously demonstrated, the participants in this study exhibited complex perception behaviors as they interacted with the course materials. In this theme, we will examine how learners' views of themselves helped mediate their behaviors as they learned the content within the confines of the system. This self-perception empowered the participants to locate themselves within the system in order to best leverage given resources. In this way, the participants' self-perception of themselves as learners situated them as owners of their own learning with varying degrees of centralization.

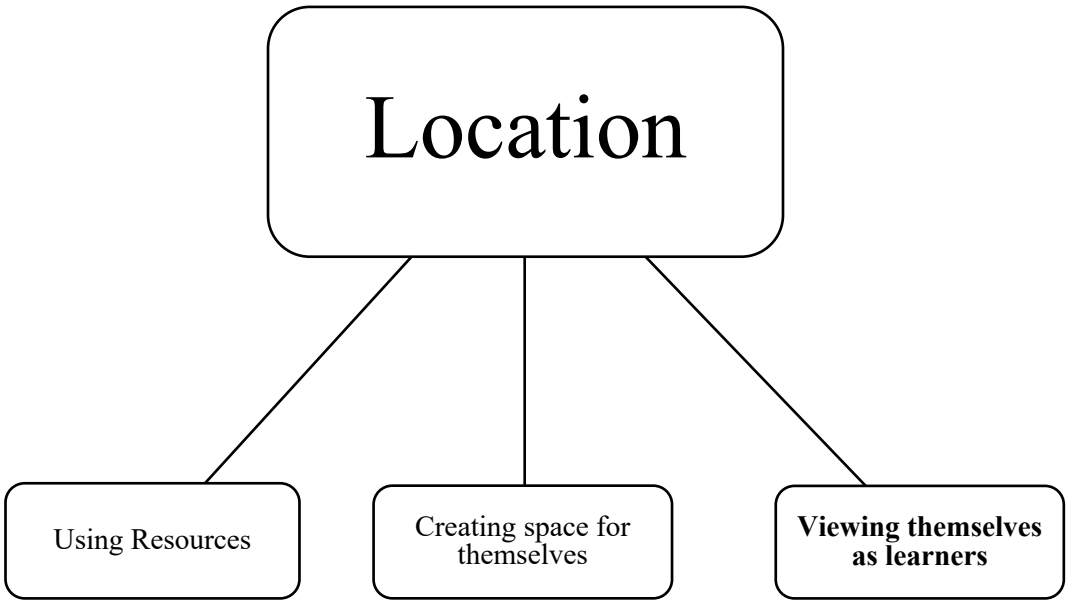

Figure 4.17. Subtheme: Viewing Themselves as Learners

Interestingly enough, 18 of the participants reported their learning style as visual, with one stating that she was a hands-on learner, one reported being a physical learner, and one stated that she had to "write everything down" (Samantha, personal communication, November 23, 2020). The most important part of the finding is that participants had different ideas about what

being a visual learner entailed. A basic definition of a visual learner would be someone who prefers instruction "emphasizing visual presentation of information" (Pashler et al., 2009, p. 105). Although this definition is quite straightforward, the participants had varying ideas of this style, reporting being a visual learner based on their own perceptions of what being this type of learner means. For example, while Olivia stated "I'm a visual learner. I have to see and hear what is going on" (personal communication, November 19, 2020), which is clearly aligned with the common definition of the style, while Jennifer believed she was a visual learner though "sometimes I was reading but didn't understand fully" (personal communication, November 20, 2020), when reading is a clear indicator of a visual learner.

Regardless of their individual definition of learner type and how they placed themselves in a particular category, the participants used their own perceptions of their learning style to locate themselves as learners within the system. Sandra believed that she was a physical learner because "I learn the best by physically seeing how things are done, by looking at it" (personal communication, November 19, 2020). Although her categorization of her learning style does not correlate to current models, she was still able to create a space for herself as a learner based on who she thought she was.

Some learners were correct in their categorization. For example, Jennifer had very specific reasoning for classifying herself as a visual learner as she discussed her learning style, "I think I'm a visual learner. I have to have the image and text to convey the information, because sometime I was reading but didn't understand fully until I saw the image of what they were talking about" (personal communication, November 20, 2020) While many of the participants were correct in identifying themselves as visual learners, they located themselves in relation to their own learning in various ways. Some reported being more in control of their own learning.

Daniela was quite honest when discussing her role in this class, “I thought I was teaching this because I was studying more. While I study, I sometimes miss things, and I felt like I was reading, like, twice or, like two or three times so I can fully understand what I was seeing” (personal communication, December 5, 2020). While she still relied on the professor’s recorded lectures, the amount of time and interaction with the materials led her to believe that she was in control of her own learning. Still others who identified themselves as visual learners placed themselves in a position where they perceived the instructor as having more control of their learning. This centralization did not inhibit their learning. Rather, it simply allowed the participant to position herself in relation to centralization of control that optimized her learning experiences in relation to what she perceived as her learning needs.

4.4 Summary of Findings

The analysis identified three themes in the data, each of which was further subdivided into three subthemes. The first of these is student perception, a theme frequently identified in the literature regarding online instruction. This theme includes ease of use, restrictiveness, and comparing themselves to others. Ease of use refers to the ease with which the participants learned to use and navigate both the LMS and adaptive courseware. In the interviews, the participants reported that they did not feel restricted by the LMS and adaptive courseware, however this theme was obvious elsewhere in the narrative when discussing how the course could have improved its usage of the adaptive courseware.

With this theme of student perception, three quantitative correlations were reported. First, there was no significant relationship between the time participants spent on adaptive courseware activities and their final grade in the course, $r_s = .260$, $p = .058$. Second there was a significant relationship between the participants’ access of content through the LMS during this time and

their final grade, $r_s = .531$, $p < .001$. Third, there was no significant relationship between the participants' access of adaptive courseware content during this time and their final grade, $r_s = -.015$, $p = .912$.

The second theme the qualitative data identified was relevance. It too was further subdivided into three subthemes, including navigating the system, prioritizing usefulness, and reaching goals. Navigating the system includes how the participant navigated the delivery modality, the LMS or the adaptive courseware; used the learning needs to mediated modality navigation; and how they optimized their system usage based on needs. Within this theme, two quantitative correlations were reported. First, there was a significant relationship between the number of LMS content hits during this time and their score on Exam 4, $r_s = .347$, $p = .008$. Second, there was no significant relationship between the participants' confidence level with the adaptive courseware content during this time and their score on Exam 4, $r_s = .122$, $p = .379$.

The final theme, location, includes the subthemes using resources, creating space for themselves, and viewing themselves as learners. The first of these, using resources, explores how student located themselves in relation to the different resources to leverage their learning preferences as they decentralized learning. The second theme, creating space for themselves, includes how the participants used technology and resources in tandem to create a customized learning space. The final theme, viewing themselves as learners, provides insight into how the participants' view of themselves mediated behaviors with the content. Included with this theme, there were two quantitative correlations. First, there was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their score on Exam 4, $r_s = .298$, $p = .028$. Second, there was a significant relationship between the amount of

time participants spent on the adaptive courseware during this time and their total score on adaptive courseware assignments, $r_s = .398$, $p = .004$.

Chapter 5: Conclusions

To answer this study's primary research question and the subquestions, qualitative data consisting of 21 semi-structured interviews and five follow-up interviews, and quantitative data composing student usage from the LMS and adaptive courseware were analyzed. In accordance with the QUAN→QUAL convergent method utilized by this study; the two data types were merged to answer the questions.

To best present the conclusions based upon the data, this chapter is organized into five sections. The first presents the conclusions based upon the qualitative data. This section is divided into three sections related to the primary themes: student perception, relevance, and location. Each of these themes is further subdivided into their subthemes. The subthemes are discussed in relation to the question that they answer.

The second section presents the conclusions based upon the quantitative data, the results of seven correlations using Spearman's rho. This section is divided into two subsections. The first of these presents the conclusions based upon the data provided by CogBooks, the adaptive courseware utilized by the biology course that was the focus of this study. The second presents the conclusions based upon the data from Blackboard, the learning management system used in this same course.

The third section presents a summary of the conclusions organized by research question. By organizing the conclusions by research question, this section is able to more fully intertwine the themes and trends identified through the analysis.

The fourth section connects the conclusions of this study to the broader context. These broader connections include a deeper understanding of what the term adaptive actually means within the context of online education and how the concept of the CLE could impact educational

technology research. This section discusses of this study's broader connections to educational technology research in general and to online instruction in particular. This study's identification and description of the CLE is discussed in relation to education research, before concluding with an examination of the study's contribution to research on adaptive learning.

The fifth section discusses suggestions for educators. Further developing upon the previous section, this section examines how the three themes identified in this study, perception, relevance, and location, can be utilized in developing online instruction that focuses on the learner.

5.1 Qualitative Conclusions

As discussed in Chapter 4, there were three themes identified in the qualitative data. Each of these three themes was further divided into three subthemes. Figure 5.1 depicts the relation of each theme to the primary research question. Each of the primary themes had one subtheme that directly helped answer the primary research question.

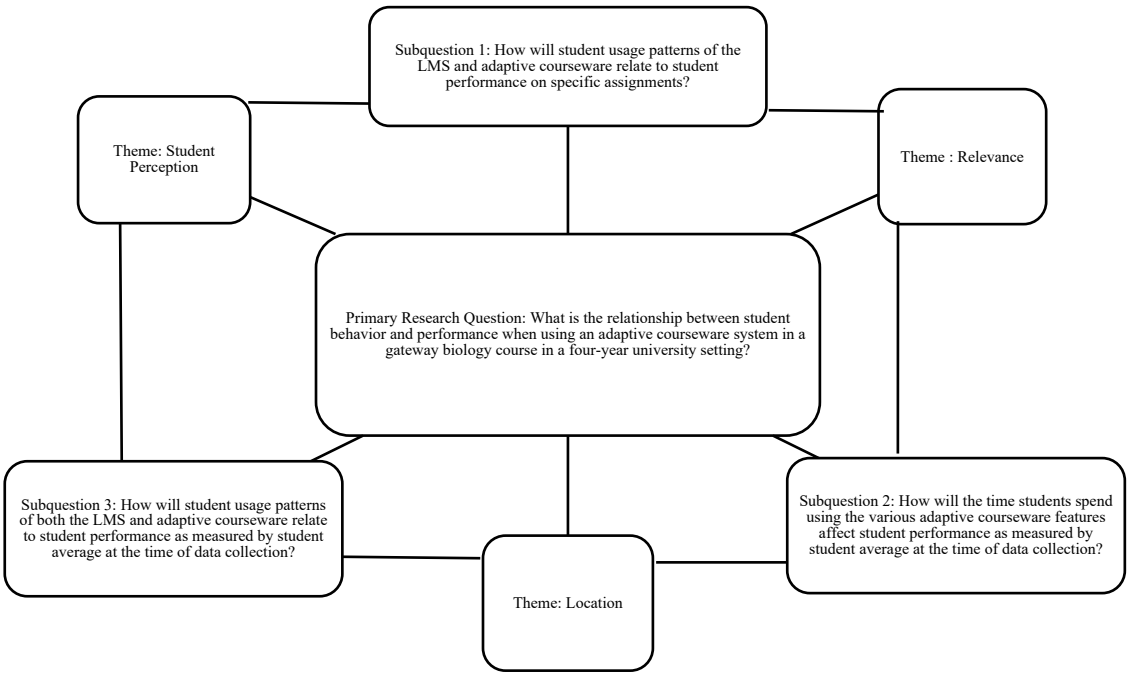

Figure 5.1. Relationship of Questions and Themes

After analyzing the data, the researcher found that the following subthemes are related to the primary research question: Theme: Student perception, Subtheme: Restrictiveness; Theme: Relevance, Subtheme: Reaching Goals; Theme: Location, Subtheme: Creating Space for Themselves. These specific subthemes as they relate to the primary research question are depicted in Figure 5.2.

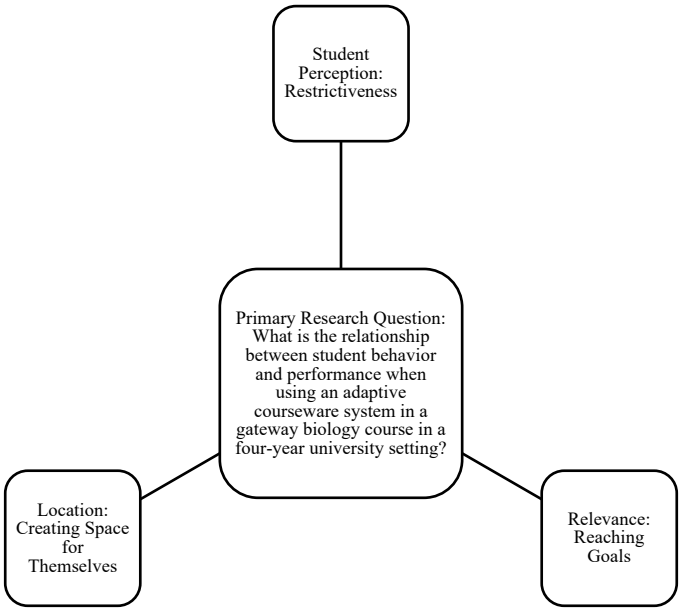

Figure 5.2. Primary Research Question Related to Subtheme

Furthermore, the researcher ascertained that each of the themes included subthemes that are related to two of the subquestions. These relationships are depicted in Figures 5.3 to 5.5.

The first of these questions is Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? This subquestion was addressed by the subtheme Ease of Use from the theme Student Perception and the subtheme Prioritizing Usefulness from the theme Relevance as depicted in Figure 5.3.

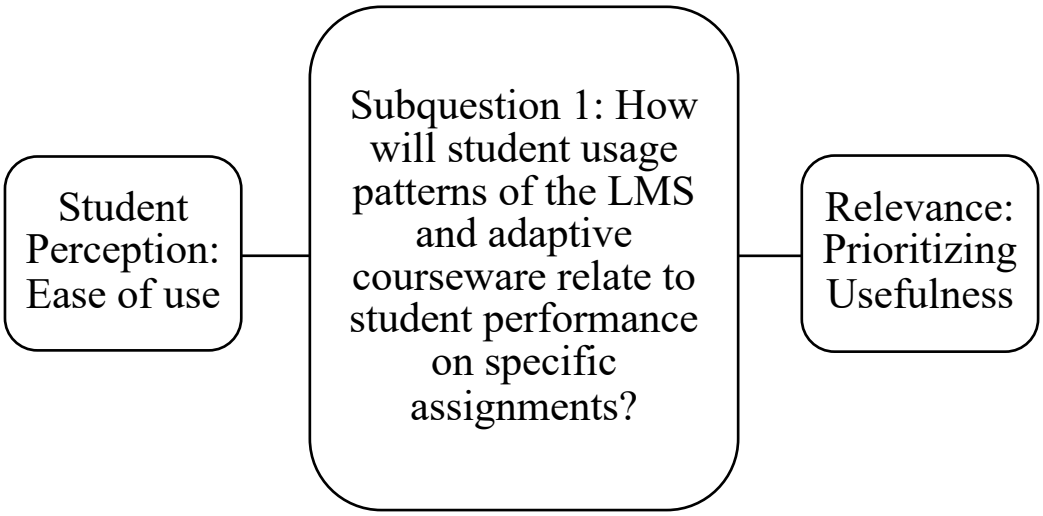

Figure 5.3. Subquestion 1 Related to Subthemes

The second subquestions asks: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? This subquestion was answered by the subtheme Using Resources, which is part of the theme Location and the subtheme Navigating the System, which is part of the larger theme Relevance. The relationship between these two subthemes and subquestion 2 is depicted in Figure 5.4.

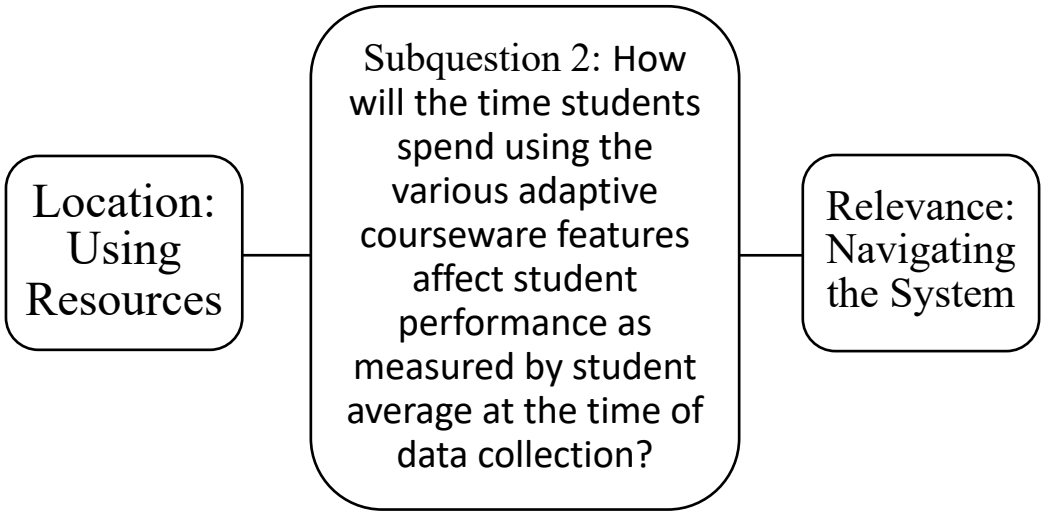

Figure 5.4. Subquestion 2 Related to Subthemes

Finally, subquestion three is also addressed by two subthemes identified in the qualitative data. The subtheme Viewing Themselves as Learners, from the theme Location and the subtheme Comparing Themselves to Others, from Student Perception both help explain how student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection. Figure 5.5 depicts the relationship between these two subthemes and subquestion three. The participants' view of themselves and others helps answer this question, because it provides insight into the relationship participants identified between behaviors with the LMS and the adaptive courseware with their performance in the course.

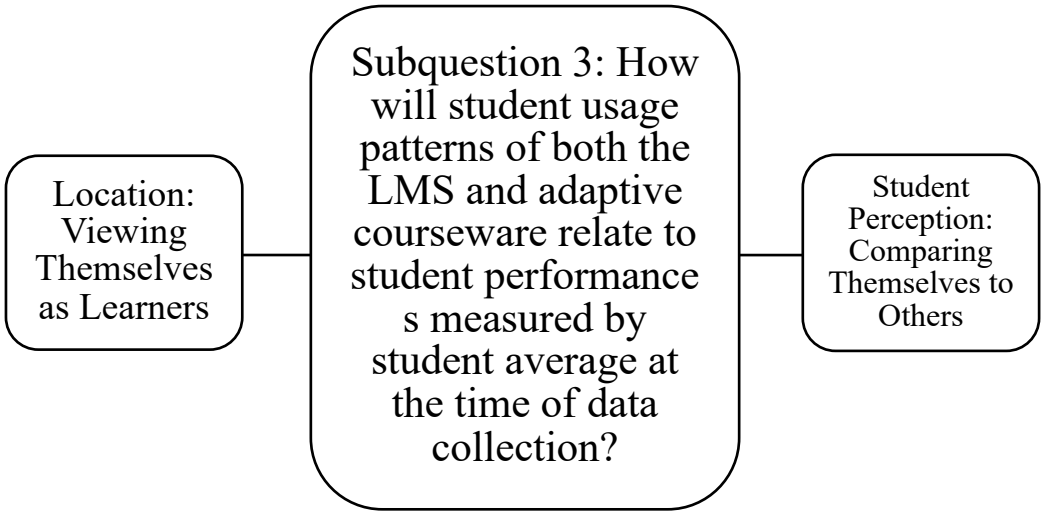

Figure 5.5. Subquestion 3 Related to Subthemes

5.1.1 Student Perception

As demonstrated in the findings, student perception includes three subthemes. The first, ease of use, helps to answer subquestion one: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? The second,

restrictiveness, is related to the primary research question: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? The third subtheme, comparing themselves to others, partially addresses subquestion three: How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection?

5.1.1.1 Ease of Use

The participant's perception of the ease of use of the LMS and adaptive courseware affected how they used these two systems, in turn influencing their performance on individual assignments. Acting as an enabling constraint, their perception of ease of use determined how and when they would use these systems. The students used CogBooks' tools, including the check for understanding feature, to ensure that they understood particular concepts. By ensuring that they learned key concepts in individual modules, they then increased their chances of performing better on individual assignments.

As depicted in Figure 5.6, this subtheme addresses Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? In general, the participants found the LMS and adaptive courseware easy to use. More important than how to use the system was determining when to use the LMS and adaptive courseware. One of the major features of CogBooks was the sliding scale with which the participants could record their confidence with a particular element of content during an activity. Participants utilized this tool in two primary ways. Some admitted that they always just reported that they were confident with the material so that they could move to the next module. This type of behavior would at best have no impact on their performance on individual assignments and at

worse negatively impact their score on related assignments. Interestingly, though, some students stated that they underreported their confidence so they could reinforce their knowledge about specific content as they reviewed concepts. By manipulating this feature, the participants were then able to review material.

While this adaptive feature is designed to provide students with reinforcement when needed, the ease with which it is used becomes an enabling constraint because it allowed the participant to produce a new outcome from a feature with one primary purpose. This reinforcement should have benefited students through improving their performance on specific assignments. This theme demonstrates, though, that even with the lack of evidence to back up this behavior's relation to improved performance, the participants themselves perceived this behavior as being beneficial. A more orthodox use of this feature is more directly connected to performance. Some participants reported their confidence levels as accurately as possible, believing that allowed the system to provide additional resources only when needed. They also felt that the quizzes provided after they reported their confidence helped them monitor their own understanding, improving their performance in the course. Although this does not reflect a usage of the feature as an enabling constraint, this method does directly address subquestion one. Participants monitored their performance through the LMS as well. By monitoring their performance in the course at different levels—specific lessons, unit tests, and final average—with the adaptive courseware and LMS tools the participants were able to track their performance constantly.

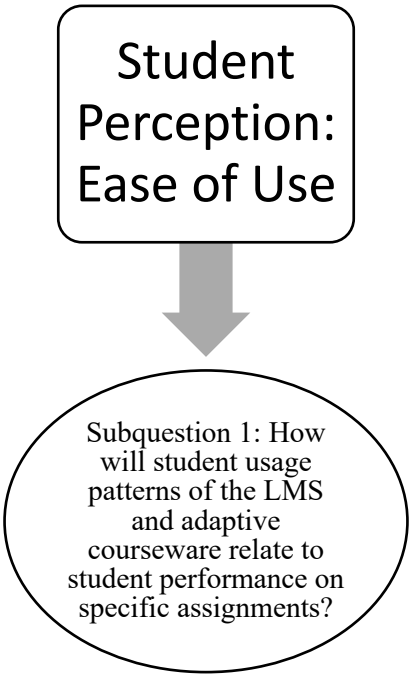

Figure 5.6. Subquestion 1 Related to Ease of Use

5.1.1.2 Restrictiveness

While most of the participants responded that they did not find CogBooks restrictive, the opposite was evident throughout the qualitative data, particularly in the follow-up interviews. The participants felt that CogBooks, within the online confines of the course, was restrictive because the adaptive courseware would have benefited from some type of FTF classroom discussion. The lack of online discussion forums provided opportunities for the participants to transcend this limitation through navigation of the CLE—the adaptive courseware and the LMS in all their aspects, the professor's content, the professor, and themselves.

As related in Figure 5.7, restrictiveness addresses the primary research questions: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? When directly asked if they felt restricted by the adaptive courseware, the participants reported that they did not. However, during the narrative, feelings of restriction did arise. This subtheme helps address the primary

research question through its identity as an enabling constraint. By perceiving themselves as being restricted, the participants liberated themselves with innovative learning techniques and behaviors that then influenced their performance in the course.

The participants also felt restricted by the adaptive courseware because of the sheer amount and variety of resources. The number of resources to negotiate in the adaptive courseware caused participants to spend considerable time in CogBooks. Although this may appear as a simple requirement of the courseware, viewing it as a restriction is more accurate. The time spent in the adaptive courseware was time not spent elsewhere, either in this course or in another. Therefore, this restriction heavily influenced their behaviors in this course and in others.

How restricted the participants perceived their behaviors within the CLE helps define the relationship between student behavior and performance. Through perceiving themselves as restricted in their actions within the adaptive courseware, they were paradoxically less restricted in the CLE. As an enabling constraint, this perception of restrictiveness helped the participants modify their behaviors in such a way that they were less restricted. This, in turn, influenced performance because it freed the participants to modify their behaviors to maximize their opportunities for content acquisition.

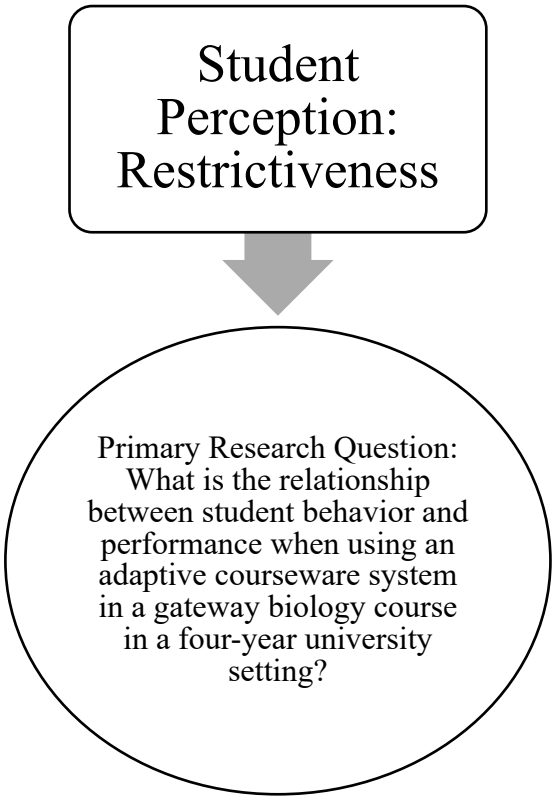

Figure 5.7. Primary Research Question Related to Restrictiveness

5.1.1.3 Comparing Themselves to Others

How participants compared their own behaviors using CogBooks to their peers helps to answer how their usage patterns affected their performance in the course, see Figure 5.8. In general, there were two different views of using CogBooks: using it to learn or just to earn the associated participation points. Generally, participants tended to view the worst of their peers' usage of CogBooks, believing that others were simply using CogBooks to earn the participation points related to the assignment's completion. Sometimes this interpretation of their peers' behavior coincided with how they themselves used CogBooks because they were using it for the same reasons. For others this perception differed from their and their peers' usage because they believed that they were all using CogBooks to learn the content. Those who stated they were using it to learn perceived usage as mediated by goals, casting performance in the course as

necessitated by objectives. Conversely, those who believed that they and others were generally just using CogBooks for the participation points were justifying their behavior through collective behavior patterns. By comparing themselves to each other, the participants' behavior in this instance is an example of an enabling constraint because it allowed them to self-reflect in such a way that it contextualized their own behaviors.

By comparing themselves to others, the students were able to moderate their behaviors in connection to their goals. Their behaviors were influenced by how they viewed themselves in relation to others. This perception of themselves negotiated through how they perceived others' behaviors influenced their usage of both the LMS and adaptive courseware.

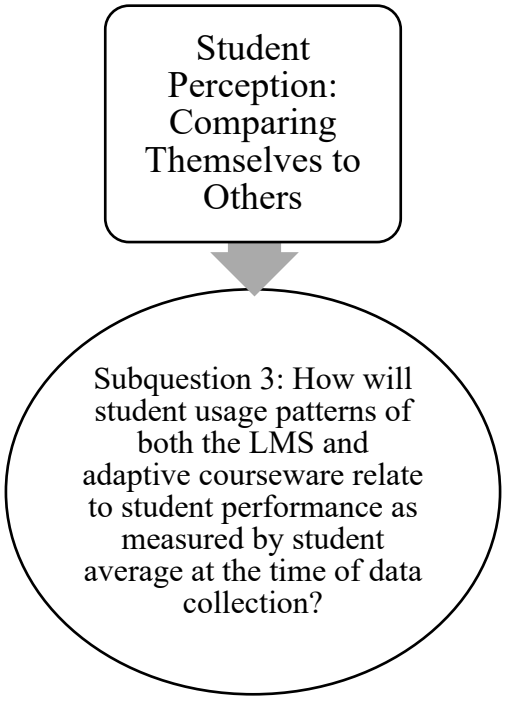

Figure 5.8. Subquestion 3 Related to Comparing Themselves to Others

5.1.2 Relevance

Relevance contains three subthemes: navigating the system, prioritizing usefulness, and reaching goals. Navigating the system helps answer subquestion two: How will the time students

spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? Subquestion one: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? is partially answered by the subtheme of prioritizing usefulness. The final subtheme of relevance, reaching goals, helps answer the primary research question: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting?

5.1.2.1 Navigating the System

The students navigated the system mediated by specialization, that characteristic of a complex system that includes internal diversity and redundancy that ensures the system's continuance. As seen in Figure 5.9, system navigation helps answer subquestion 2: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? This navigation of the CLE resulted in a system customized for each individual based upon her learning needs. The learning needs that influenced system navigation can be categorized as situations in which the participant needed to study content in depth because of lack of familiarity, or situations where the participant could skim through information because they were already comfortable with it. By navigating the system based upon these learning needs, the participants could optimize their usage of the system. This usage optimization would not only increase learning opportunities for the participant, but would also optimize time consumption.

Student navigation of the courseware is related to time in two instances. First, how the students navigated the adaptive courseware is an indicator of the time they spent with the courseware. In this instance their navigation choices helped influence the time they spent with

the courseware. Second, the time they spent within the adaptive courseware influenced how they actually used it. In this way, time spent is both a product of navigating the system and an indicator of how the system is navigated.

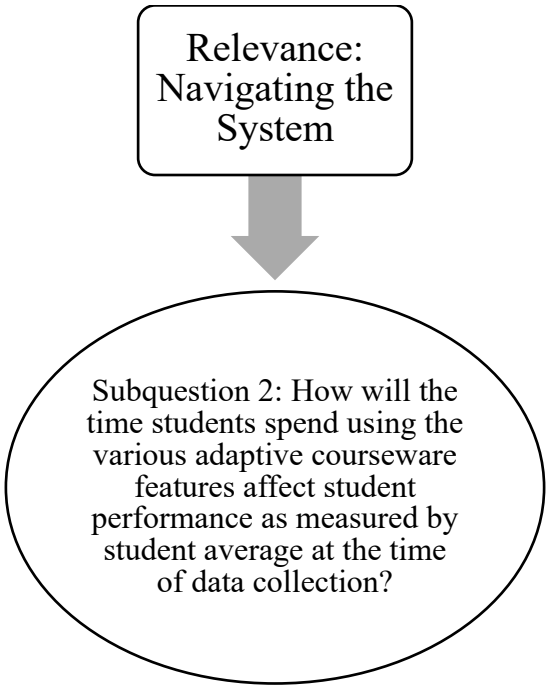

Figure 5.9. Subquestion 2 Related to Navigating the System

5.1.2.2 Prioritizing Usefulness

Prioritizing the usefulness of a given source allowed participants to concentrate on those sources that could best influence their performance in the course and in individual assignments. As seen previously, this subtheme is an instance of specialization because the participants are able to balance the diversity and redundancy within the various resources to most positively impact their performance in the course. As related in Figure 5.10, this subtheme Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? Participants framed their discussion of usefulness both in terms of grades and learning. This prioritization allowed the participants to create a system customized for their performance. Participants prioritized the usefulness of resources, either from

CogBooks or those provided through the LMS by the professor, based upon the level of learning that they deemed a particular topic warranted.

Participants prioritized CogBooks' activities highly, even given their perceived difficulty because of their relevance to increased student performance. Even though participants characterized some of these activities as difficult and tricky, their perceived usefulness made the participants rank them highly because these activities helped them understand the content. Therefore, usefulness outranked difficulty for the participants.

Although this theme cannot directly address how students performed on a particular assignment, it does demonstrate how students moderated their student usage patterns. Given the number of resources available through the LMS and the adaptive courseware, the students had to prioritize the usefulness of the resources, or be inundated with materials that were irrelevant to a particular learning need. In relation to this question, the participants were not so much operating within the LMS or the adaptive courseware, rather they were prioritizing usefulness to create a set of resources from both systems to create a customized learning environment. This behavior most certainly was reflected throughout the course, from CogBooks' activities and quizzes to more comprehensive exams that covered content from across the resources.

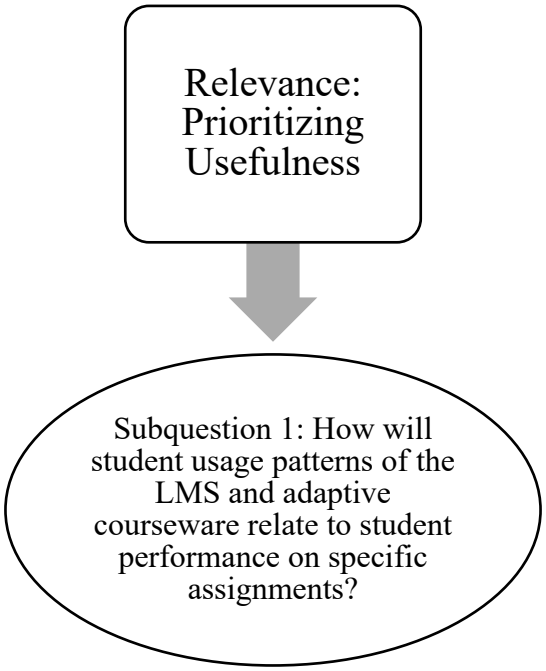

Figure 5.10. Subquestion 1 Related to Prioritizing Usefulness

5.1.2.3 Reaching Goals

Figure 5.11 demonstrates how this subtheme helps answer the Primary Research Question: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? The relationship between student behavior and performance within an adaptive courseware system is partially addressed in the theme of how the participants prioritized relevance through their need to reach their goals. Reaching goals through prioritizing relevance is another instance of specialization because the participants were able to balance the diversity and redundancy of the various resources as they sought to use the resources to meet their individual goals. In turn, these goals represent specialization because, among the participants, elements of their immediate, short-term, and long-term goals were at times diverse and at times redundant. Even though each of the participants had long-term goals that required a strong foundation in biology, they still chose resources that they felt would most benefit their own acquisition of the required

knowledge. This included either CogBooks resources or professor-provided resources, depending on their individual needs. The participants used their goals to mediate their behaviors in the system.

The participants utilized their long-term, short-term, and intermediate goals to adjust their behaviors within the adaptive courseware. Although this theme does not directly address performance, the participants performance is definitely an aspect this theme. Each of these goals is directly related to performance. Long-term goals, including career paths and further education, were predicated upon successful completion of the course. Short-term goals, passing the class in order to have the necessary prerequisite for further study, were directly related to performance. Immediate goals, doing well on specific assignments, are the foundation for the other two goals. As such, these goals influence student behavior because the students adjusted their behaviors as they monitored their performance in relation to the goals.

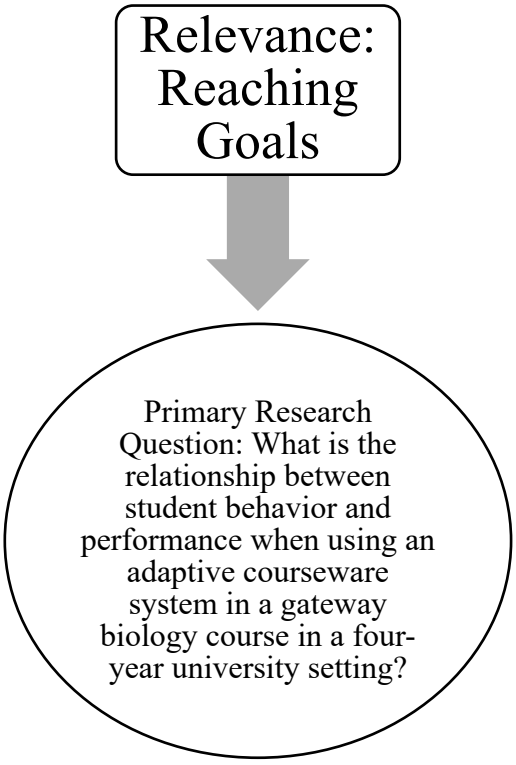

Figure 5.11. Primary Research Question Related to Reaching Goals

5.1.3 Location

Location includes three subthemes: using resources, creating space for themselves, and viewing themselves as learners. Using resources helps to answer subquestion 2: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? The primary research question: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? is partially addressed by the subtheme creating space for themselves. Finally, the subtheme, viewing themselves as learners, addresses subquestion three: How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection?

5.1.3.1 Using Resources

In this course, the participants had a variety of resources to choose from. How participants created a customized learning location for themselves by using resources, as seen in Figure 5.12, addresses Subquestion 2: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? CogBooks provided various resources including videos, readings, quizzes, and matching exercises. The professor provided resources such as PowerPoint presentations, recorded mini-lectures, YouTube videos, and optional exercises. Predispositions toward reading and time constraints were factors that mediated resource choice for the participants. This subtheme is an instance of trans-level learning, because it is representative of neighbor interactions and decentralization of control.

Although the participants did not have a tremendous number of interactions with their peers, this lack was somewhat mitigated by their interactions with the professor, through direct communication and asynchronous lectures. Another key component of trans-level learning is decentralization of control. As the participants used the many resources made available in this course, they were able to decentralize learning through individual agency that allowed them to use those resources without reliance on a centralized controlling structure. While some of the participants relied on the CogBooks resources because of their lack of time, others chose the professor-provided resources for the same reason. This demonstrates how participants used their predispositions to position themselves closest to the resources that met their learning needs thereby creating a space for themselves within the CLE that maximized their chances for learning.

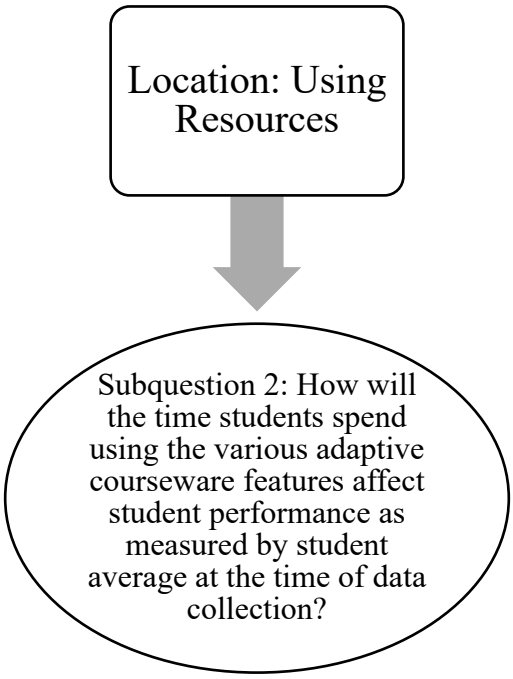

Figure 5.12. Subquestion 2 Related to Using Resources

5.1.3.2 Creating Space for Themselves

Closely related to using resources, the subtheme creating space for themselves helps explain the relationship between student behavior and performance when using adaptive courseware, see Figure 5.13. This subtheme is another instance of trans-level learning because the participants were able to use the varied resources provided throughout the course to virtually locate themselves closer to some and more remotely to others, to create a customized learning space.

By using the adaptive courseware within the context of the CLE, the participants were able to create a virtual learning space of their own. The participants were able to separate the content provided through the adaptive courseware from the courseware's technology through note taking. This theme actually demonstrates how the participants were able transcend the adaptive courseware by creating a learning space unique to their own needs. They were also able to flexibly utilize the resources provided through CogBooks by using the technology as delivered through mobile devices. By creating a space for themselves in the comprehensive learning environment through using the adaptive courseware in connection with the other elements in the environment, the participants were able to optimize their chances for learning, thereby increasing their performance in the course.

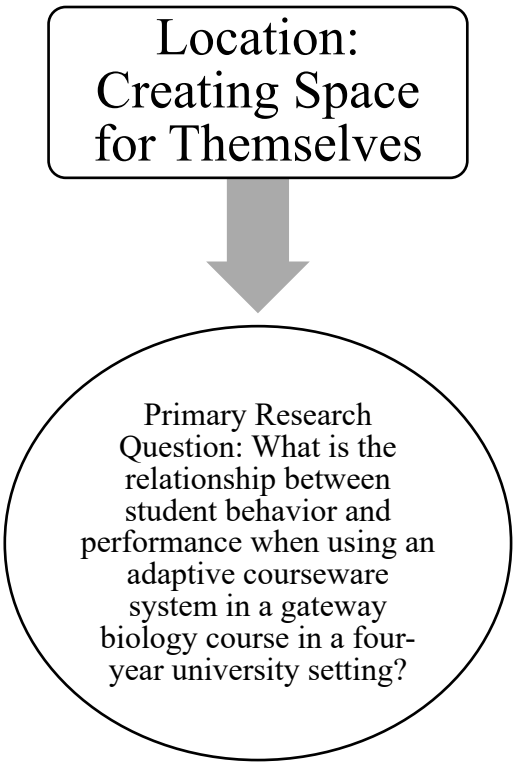

Figure 5.13. Primary Research Question Related to Creating Space for Themselves

5.1.3.3 Viewing Themselves as Learners

The participants' view of themselves as learners helps to explain how their usage patterns of both the LMS and adaptive courseware related to their performance because this view helped mediate their behaviors within the comprehensive learning environment, see Figure 5.14. This personal view is an instance of trans-level learning, because it is a strong mediating force that allowed them to modulate their interactions with others and decentralize control of their learning, through carefully locating themselves within the CLE. Most of the participants viewed themselves as visual learners, which is in itself telling given that few of them had any formal learning style assessment and were judging themselves based upon previous educational experiences. Although some of this self-assessment was inaccurate, this belief, however unfounded, informed their usage patterns in both Blackboard and CogBooks. The participants

utilized their view of themselves as learners to exercise personal agency to decentralize control of the CLE.

Although not directly related to final course average, how the students viewed themselves as learners moderated their behaviors with both the LMS and the adaptive courseware by providing them with justification for their choices in resources and assignments. In turn, these choices became the building blocks of their usage patterns. Participants, guided by what they saw as their learning styles, made choices as they navigated the LMS and the adaptive courseware. These choices therefore facilitated the creation of the CLE as a whole.

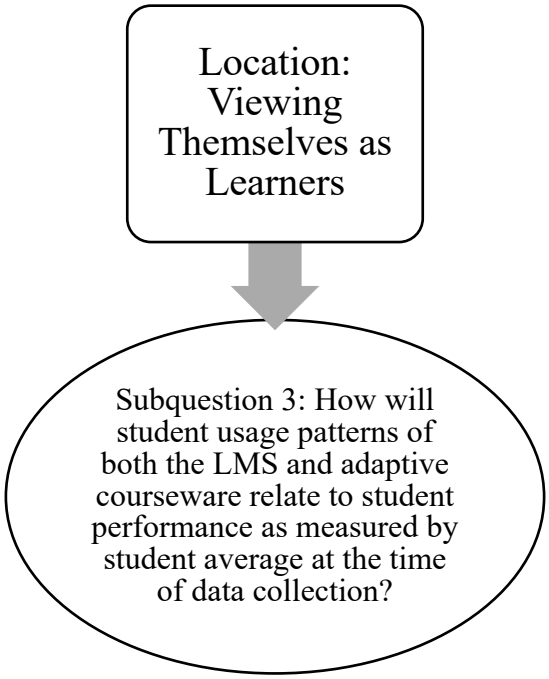

Figure 5.14. Subquestion 3 Related to Viewing Themselves as Learners

5.2 Quantitative Conclusions

Although the quantitative data was reported with its related qualitative theme, in this section, the quantitative conclusions are presented here separately because they more directly

answer the subquestions. In section 5.3 Broader Conclusions, the conclusions from both data types will be combined to explore the larger ramifications of the study.

5.2.1 CogBooks Data

As seen in Figure 5.15, the correlation between the participants' score on Exam 4 and their CogBooks confidence level helps to answer Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? There was no significant relationship between the participants' confidence level with the adaptive courseware content during this time and their score on Exam 4, $r_s = .122$, $p = .379$. While there was no statistically significant correlation between these two, this relationship is still an example of specialization because it helps describe the diversity and redundancy inherent to the participants' confidence as they learned specific content in relation to their performance on a specific assessment.

Although there was no significant relationship between these two variables, this data still provides some clarification for this question. Exam 4 was the major assessment taken during the quantitative data collection window. The confidence level is an average of the students' reported confidence with non-assessment content measured through a slide bar that records their confidence each time they access the content. One of the possible reasons that there was no correlation between these two variables is that Exam 4 tested students on material not covered in the adaptive courseware. This means that the participants' reported confidence level did not correspond to their confidence with all the material tested. Furthermore, as indicated in the qualitative data, many students reported a higher confidence level than they actual held in order to proceed to the next activity. While this is an inherent weakness in the adaptive courseware, it still provides insight into the students' usage of the system. As the participants navigate the

adaptive courseware system with behaviors indicated through the themes of perception, location, and relevance, the participants utilized the system in the manner that most fit their needs, not necessarily in a manner that is reflected through performance on individual assessments.

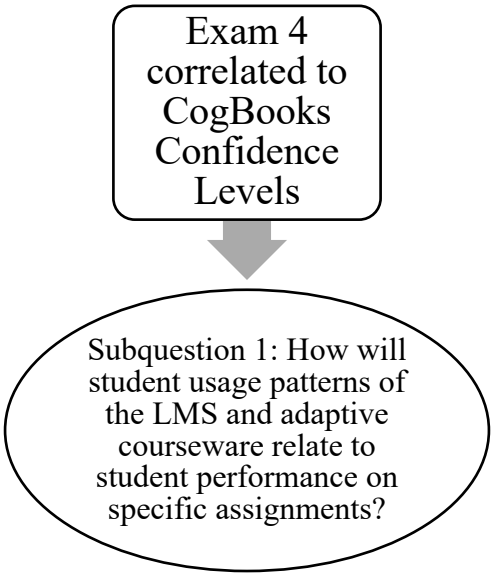

Figure 5.15. Subquestion 1 Related to the Correlation between Exam 4 and CogBooks Confidence Levels

As depicted in Figure 5.16, the relationship between students' performance on Exam 4 and the time they spent on adaptive courseware activities during the data collection window helps to answer Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments. There was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their score on Exam 4, $r_s = .298$, $p = .028$. This positive association is an example of trans-level learning because it helps contextualize the relationship between decentralization of control and interactions with participant performance on a specific assessment. Spending time in the courseware, where they have more control over their learning is associated with better performance on Exam 4.

Exam 4 is used in this instance as the specific assignment on which this question focuses. In this case the amount of time participants spent using the adaptive courseware was associated positively with their score on this assignment. Although Exam 4 included material not specifically addressed in the courseware activities, the courseware still provided the participant with the ability to engage with some of the material addressed in this assessment. Spending time in the courseware is indicative of location, one of the themes the qualitative data identified. The time spent in this resource indicates that students used the resource as part of the process of creating customized learning spaces for themselves.

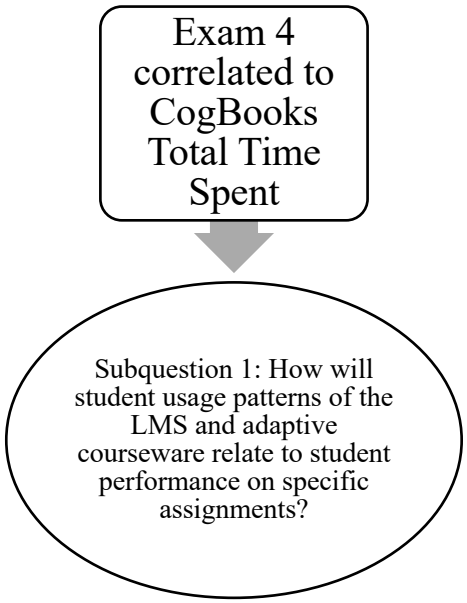

Figure 5.16. Subquestion 1 Related to the Correlation between Exam 4 and CogBooks Total Time Spent

As seen in Figure 5.17, the correlation between CogBooks Total Time Spent and the participant's CogBooks Average Score helps answer Subquestion 2: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? There was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their total

score on adaptive courseware assignments, $r_s = .398$, $p = .004$. As in the previous correlation, the relationship described here is also an example of trans-level learning because it helps to illuminate the association between time spent in a decentralized learning environment with performance in the course, in this case an average of their adaptive courseware assignments and activities during the data collection window.

This correlation helps to answer subquestion two, because it provides another dimension to what is meant by student average. As seen previously in findings, and discussed later in this section, there was no significant relationship between the time participants spent on adaptive courseware activities and their final grade in the course, $r_s = .260$, $p = .058$. However, final grade in the course is only one element of student average. Another dimension of this metric is the average score of CogBooks activities during the data collection window. In this instance, a positive correlation makes sense because both of the metrics are within the adaptive courseware. The association between the time the participants spent within the adaptive courseware and how they performed on assignments and assessments within the courseware suggests that increased time spent benefited their performance.

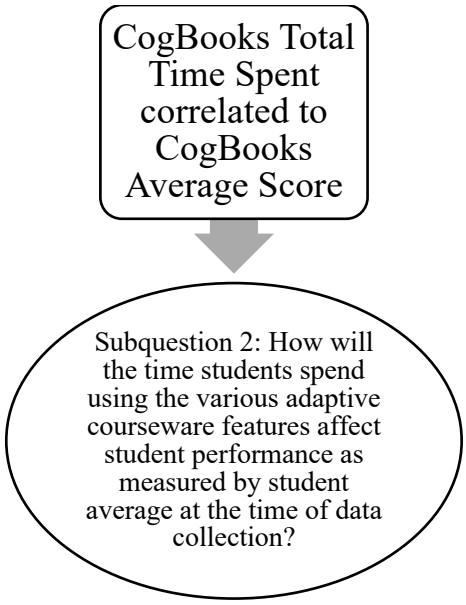

Figure 5.17. Subquestion 2 Related to the Correlation between CogBooks Total Time Spent and CogBooks Average score

As Figure 5.18 depicts, the correlation between the participant's final average and CogBooks Total Time provides a partial answer to Subquestion 2: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? There was no significant relationship between the time participants spent on adaptive courseware activities and their final grade in the course, r_s = .260, p = .058. Although there was no significant relationship between these two variables, the comparison between them is an example of an enabling constraint given that the dependent variable, final average, represents the average of a number of assignments not directly related to the time participants spent with the adaptive courseware during the data collection window.

It may seem unintuitive that there was no significant relationship between these two variables when the data has already demonstrated a significant positive relationship between time spent on the adaptive courseware and the participants' grade on Exam 4. A possible explanation for this is that the final grade reflects a variety of disparate assignments, some of which included

content not directly related to the adaptive courseware activities. Another possible explanation is that, given that the quantitative data collection window for the adaptive courseware data was at the end of the semester, the time spent on the adaptive courseware during the window cannot be related to the final average, which includes activities and assignments that occurred throughout the semester. This correlation cannot account for changes in the students' behaviors throughout the semester. However, this lack of significant relationship still provides some insight into student behaviors with the adaptive courseware because it seems to indicate that the students' engagement with the courseware is not related to their course performance.

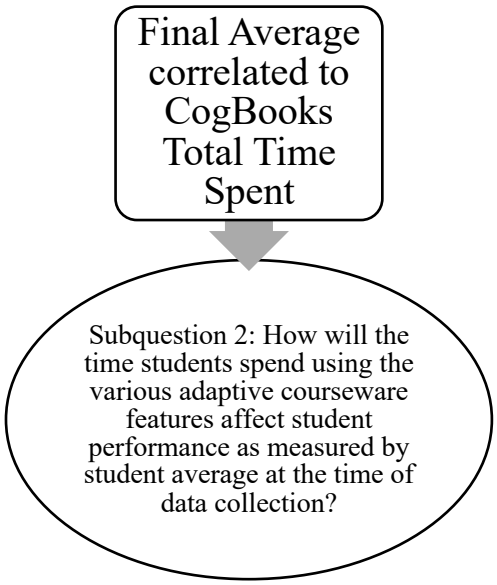

Figure 5.18. Subquestion 2 Related to the Correlation between Final Average and CogBooks Total Time Spent

As demonstrated in Figure 5.19, the correlation between the participants' final average and CogBooks Activity Hits helps answer subquestion 3: How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection? There was no significant relationship between the participants' access of content through the adaptive courseware during this time and their final

grade, $r_s = -.015$, $p = .912$. As seen in the previous correlation, the comparison between these two is an example of an enabling constraint given the nature of the dependent variable, final average, and its loose connection to the number of times participants accessed the adaptive courseware during the data collection window.

While the correlation between these two variables is not statistically significant, it still offers some understanding of student usage patterns of the adaptive courseware influenced student performance. As noted earlier, the participants' final average includes a variety of assignments not directly related to CogBooks activities. Usage patterns, as measured through the number of times the students accessed adaptive courseware activities was not associated with better performance in the class measured by final average. Although there was no association between these two variables, the amount of different data points included in the final average does not preclude there being no relation between course performance and the number of times the students accessed adaptive courseware activities.

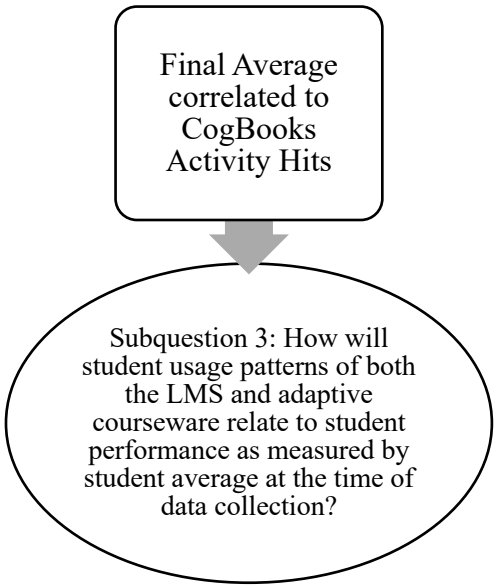

Figure 5.19. Subquestion 3 Related to the Correlation between Final Average and CogBooks Activity Hits

5.2.2 Blackboard Data

As illustrated in Figure 5.20, an examination into the relationship between the students' score on Exam 4 and their total LMS Content Hits helps answer Subquestion 1: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? There was a significant relationship between the number of LMS content hits during this time and their score on Exam 4, $r_s = .347$, $p = .008$. The association between these two variables is an instance of specialization because this relationship helps describe how internal diversity and redundancy interact to ensure the system's continuance. In this case, the LMS contains a variety of resources that provide a level of repetition and distinctiveness for the participants.

As a metric used to illuminate student usage patterns, LMS Content Hits is useful because it counts the number of times participants accessed materials through the LMS. However, it is important to remember that students' access to the adaptive courseware is part of this count, which is what the question is asking. The positive relationship between these two variables suggests that increased use of the resources available through the LMS is beneficial to student performance on specific assignments.

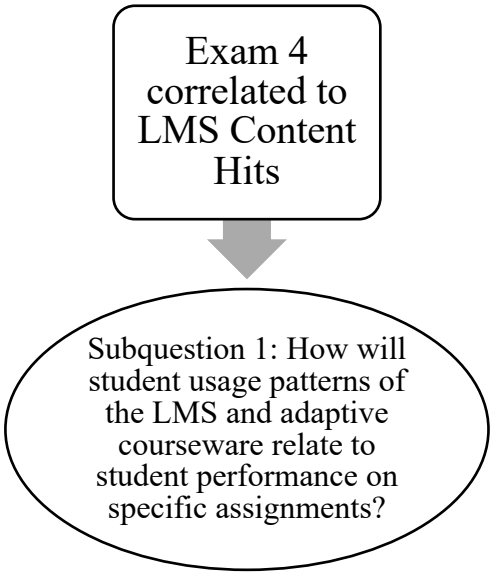

Figure 5.20. Subquestion 1 Related to the Correlation between Exam 4 and LMS Content Hits

The relationship between the participants' final grade and the number of times they accessed LMS resources, as measured through LMS Content Hits, as demonstrated in Figure 5.21, helps provide an answer to Subquestion 3: How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection? There was a significant relationship between the participants' access of content through the LMS during this time and their final grade, $r_s = .531$, $p < .001$. This significant relationship between these two variables is an example of enabling constraint in that the relationship is an example of how students can transcend the limits of a given system, in this case the LMS, by repeatedly accessing the resources that can most allow them to succeed in a given assignment.

This correlation helps explain the relationship between student usage patterns of both the LMS and the courseware, because the LMS Content Hits metric includes the number of times that participants accessed material through the LMS, including both professor-provided

resources and the adaptive courseware. This combined behavior has then been correlated to the participants' final average.

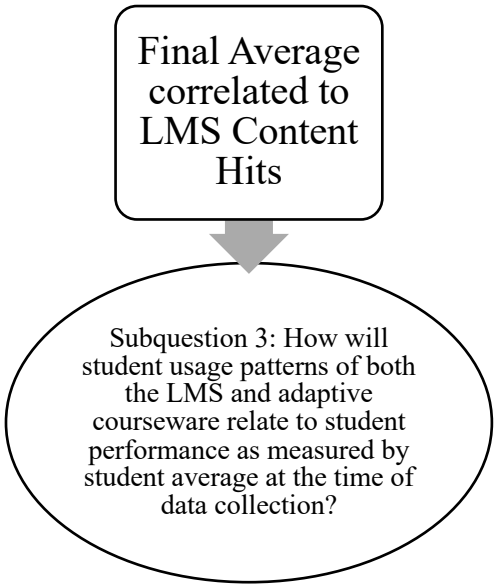

Figure 5.21. Subquestion 3 Related to the Correlation between Final Average and LMS Content Hits

5.3 Summary of Conclusions

The primary research question driving this study was: What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? After analyzing the data, the researcher found that the following subthemes are related to the primary research question: Theme: Student perception, Subtheme: Restrictiveness; Theme: Relevance, Subtheme: Reaching Goals; Theme: Location, Subtheme: Creating Space for Themselves.

When asked directly about any restriction inherent in the adaptive courseware, the participants reported in the negative, but with additional questioning, this feeling emerged throughout the narrative. This subtheme helps address the primary research question through its identity as an enabling constraint. By perceiving themselves as being restricted, the participants

liberated themselves with innovative learning techniques and behaviors that then influenced their performance in the course. The subtheme, reaching goals, addresses this question because the participants' individual goals mediated their use of the adaptive courseware and other resources by driving their decisions regarding their interactions with the various nodes in the CLE. The subtheme Creating Space for Themselves addresses the primary research question because it illuminates how the students utilized the adaptive courseware in innovative ways by using the adaptive courseware in connection with the other elements in the environment, the participants were able to optimize their chances for learning, thereby increasing their performance in the course.

The first subquestion is: How will student usage patterns of the LMS and adaptive courseware relate to student performance on specific assignments? This subquestion was addressed by the subtheme Ease of Use from the theme Student Perception and the subtheme Prioritizing Usefulness from the theme Relevance. In regards to ease of use, the participants found the LMS and adaptive courseware quite easy to use. This ease of use allowed the participants to move beyond how to utilize both systems to when to use both systems in innovative ways. The subtheme Prioritizing Usefulness demonstrates how the students framed the discussion of usefulness in terms of grades and learning, in order to prioritize their use of the various sources. The students prioritized resource usefulness based upon the level of learning that they deemed a particular topic warranted.

There was no significant relationship between the participants' confidence level with the adaptive courseware content during this time and their score on Exam 4, $r_s = .122$, $p = .379$, demonstrating that what the students reported as their confidence on specific content delivered through CogBooks did not translate to their performance on Exam 4. However, the significant

relationship between the amount of time participants spent on the adaptive courseware during this time and their score on Exam 4, $r_s = .298$, $p = .028$ demonstrates that increased time within the adaptive courseware is related to increased performance on individual assignments. There was also a significant relationship between the number of LMS content hits during this time and their score on Exam 4, $r_s = .347$, $p = .008$. The relationship between these two variables suggests that increased use of the resources available through the LMS is beneficial to student performance on specific assignments.

The second subquestion for this study was: How will the time students spend using the various adaptive courseware features affect student performance as measured by student average at the time of data collection? This subquestion was answered by the subtheme Using Resources, which is part of the theme Location and the subtheme Navigating the System, which is part of the larger theme Relevance. The participants navigated the CLE mediated through their learning needs, leading to a customized system for each participant. The participants used the various resources provided in the CLE mediated through personal predispositions such as time constraints and amount of reading to create a location for themselves within the CLE that maximized their chances for learning.

The correlation between CogBooks Total Time Spent and the participant's CogBooks Average Score helps answer this subquestion. There was a significant relationship between the amount of time participants spent on the adaptive courseware during this time and their total score on adaptive courseware assignments, $r_s = .398$, $p = .004$ indicates that increased engagement within the adaptive courseware translated to student performance in the course.

The correlation between the participant's final average and CogBooks Total Time also provides a partial answer to Subquestion 2. While there was no significant relationship between

the time participants spent on adaptive courseware activities and their final grade in the course, r_s = .260, p = .058, this might be an instance of the final grade reflecting many assignments not related to the adaptive courseware activities.

The subtheme Viewing Themselves as Learners, from the theme Location and the subtheme Comparing Themselves to Others, from Student Perception both help answer subquestion 3: How will student usage patterns of both the LMS and adaptive courseware relate to student performance as measured by student average at the time of data collection? While few of the participants had any formal assessment to determine their individual learning style, each had a firm view of themselves as learners. The participants utilized their view of themselves as learners to exercise personal agency to decentralize control of learning in the CLE. When comparing themselves to others, some participants viewed their own actions as more motivated by their goals than their peers, while others assumed that their behaviors were similar to those of the other individuals in the course. These themes demonstrate that their views of themselves and others are strongly related to their own behaviors with the LMS and adaptive courseware.

The correlation between the participants' final average and CogBooks Activity Hits helps answer subquestion 3. While there was no significant relationship between the participants' access of content through the adaptive courseware during this time and their final grade, r_s = -.015, p = .912, this relationship still offers some understanding of student usage patterns of the adaptive courseware influenced student performance, since the participants' final average includes a variety of assignments not directly related to CogBooks activities.

The relationship between the participants' final grade and the number of times they accessed LMS resources, as measured through LMS Content Hits also helps provide an answer to Subquestion 3. The significant relationship between the participants' access of content through

the LMS during this time and their final grade, $r_s = .531$, $p < .001$ helps explain the relationship between student usage patterns of both the LMS and the courseware, because the LMS Content Hits metric includes the number of times that participants accessed material through the LMS, including both professor-provided resources and the adaptive courseware.

5.4 Broader Connections

As demonstrated, the participants interacted with the adaptive courseware, the LMS, the various types of content, and the professor in what this study termed the CLE. To analyze these interactions, the dyads of enabling constraints, specialization, and trans-level learning were used. This study identified the CLE as the overarching environment in which learning was taking place during this course through two student behaviors. The first was the ability of the students to transcend the limits of the individual nodes of the system, while engaging with the system in such a way to ensure its survival. The second was the students' ability to locate themselves within the system, which are individual instances of trans-level learning. The CLE transcended the limitations of each of the disparate elements in such a way that the participant was able to exercise agency mediated by several personal factors, including goals, learning needs, and learning styles. The identification of the CLE as an entity composed of the four nodes of the didactical tetrahedron—learner, teacher, content, and technology, with the LMS and adaptive courseware, major components of the technology node, further divided into not only technology, but as resources and specific locations, will help to provide context for further examinations of online instruction.

The second major connection illuminated by this study's findings is a more in-depth concept of what adaptive means in an educational context. While previous research has focused on adaptive courseware, this study included, this study has found that the courseware is not the

only adaptive component of the CLE. Through focusing on student behaviors with the adaptive courseware with the lens of complexity theory, this study was able to use the dyads of enabling constraints, specialization, and trans-level learning to determine how the CLE was created, maintained, and utilized as a compilation of learner, teacher, content, and technology. Careful exploration helped identify the learner herself as the most adaptive node within the CLE. This adaptivity allows the leaner to navigate, interact with, and learn from the larger system, not solely the adaptive courseware, in ways that adapt to her needs. This means that any CLE is adaptive, even when an adaptive courseware is not one of the components. When provided with varied delivery modalities and resources, the learner herself can construct an adaptive system. While this course was not illustrative of certain aspects of adaptive learning as a whole, including the ability to choose one's own deadlines and content, the participants were able to construct within the CLE an adaptive environment that responded to their particular needs.

This study started out as an attempt to understand student behaviors while they used adaptive courseware. It quickly evolved from that nascent stage to address research questions that sought to illuminate the breadth of interactions between learner, teacher, content, and technology.

The primary research question provides the ideal ending place for this section. What is the relationship between student behavior and performance when using an adaptive courseware system in a gateway biology course in a four-year university setting? The answer, it turns out, is more complex than initially thought. Learning behaviors and performance are interrelated in various ways. The participants interacted with the adaptive courseware using a combination of perception and relevance to locate themselves within the CLE. Their performance was informed by their learning behaviors, though not always indicative of said behavior. Furthermore, the

participants did not define the adaptive courseware as a singular entity with which they reacted. Rather, they viewed the adaptive courseware, as well as the LMS, as three separate entities—location, resource, and technology, depending on the particular situation. This complex series of interactions with participants participated in with the LMS, the adaptive courseware, the teacher, and the content, analyzed through the concepts of enabling constraints, trans-level learning, and specialization demonstrates that the participants created adaptive learning opportunities for themselves in all aspects of the CLE, not just within the adaptive courseware.

5.5 SUGGESTIONS FOR EDUCATORS

Supportive rather than proscriptive in nature, this section intends to provide some suggestions for educators as they develop online instruction that focuses on the learner. The three themes identified in this study, perception, relevance, and location, afford educators with ideal dimensions to reflect on as they develop student-based online instruction.

The first theme, perception, is comprised of three sub-themes, ease of use, restrictiveness, and comparing themselves to others. This theme provides fertile ground for reflection as educators develop instruction. As seen earlier, perception allows the student to leverage their view of the LMS or courseware's ease of use, how restricted they feel by the LMS or adaptive courseware, and how the compare themselves to others to transcend the limits of a given system. They transcend these limits by using system features in innovative ways. As educators plan student-centered instruction, one suggestion is to reflect on the limitations of the LMS, the adaptive courseware, or other instructional technology being utilized. However, instead of reflecting on the limitation as a hindrance, one should explore the benefits of limitation. Educators often take a deficit view of instructional technologies, focusing on what they cannot do. This study suggests that the educator should focus on how the limitation inherent in a given

system acts as an enabling constraint that will allow their students to leverage the limitation to create a new avenue for learning.

The second theme, relevance, includes three sub-themes, navigating the system, prioritizing usefulness, and reaching goals. Relevance affords educators with a vital aspect of online instruction to examine. As an instructor develops online instruction, a possible suggestion she could follow related to relevance is to reflect on how she could help her students identify their immediate, short-term, and long-term goals. As seen in this study, students' goals mediated their use of both the LMS and the adaptive courseware. By helping students identify concrete goals, the instructor could facilitate this mediation process. This would provide students with the necessary foundation for leveraging relevance as they prioritized the usefulness of resources in their navigation of the LMS or adaptive courseware the course is utilizing frm the start.

The third theme, location, consists of three sub-themes, using resources, creating space for themselves, and viewing themselves as learners. As one develops online instruction, this theme offers a starting point for consideration. As seen in the findings, most of the participants viewed themselves as visual learners, even when their learning styles did not accurately coincide with the actual definition of visual learning. While having an accurate label for their learning style is not necessary, a more complete and definitive view of themselves as learners could benefit students as they work to position themselves in the CLE to create a learning space optimized for them. More accurate information about their learning preferences would better facilitate the process of location within the CLE. As they seek to decentralize learning in a course through leveraging learning preferences to create a learning space optimized for them, more accurate information about these preferences would better facilitate the process of location. To that end, teachers can provide students with a formal learning style inventory and with time

throughout the course to reflect on themselves as learners. Instructors could help students locate themselves within the course by assisting with the process students are undertaking by themselves. A more accurate view of how they learn will allow students to better locate themselves within the CLE as the course progresses, allowing for the decentralization of learning.

Although the three themes identified in this study provide many more avenues of thought for educators as they seek to develop student-centered online instruction, the three suggestions here afford a starting point for reflection. As seen in this study, students interacted with the adaptive courseware using a combination of perception and relevance in order to locate themselves within the CLE. By reflecting on perception, relevance, and location as they develop online instruction, educators can facilitate their students' interactions with the components of the CLE to increase student performance.

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Appendices

APPENDIX A: INTERVIEW QUESTIONS

1. What was your goal in this course?
2. Did you have any problems accessing CogBooks or getting the code for CogBooks?
3. Tell me about your first perceptions of using the CogBooks activities.
4. Have you used anything like CogBooks before?
5. Tell me about your first perceptions of using Blackboard.
6. Have you taken an online course before? How many?
7. Would you be taking classes online if it wasn't for the pandemic? Why?
8. Were the CogBooks activities a decent substitute for the FTF? Why?
9. Do you feel that you were teaching yourself in this course?
10. What level do you think you are at in biology? Do you think the level you were at in the subject affected how you used CogBooks?
11. Do you think the students' goals affect how they would use CogBooks? Why?
12. Tell me about the features of the CogBooks that you really enjoyed using (or found useful).
13. Tell me about the features of the CogBooks that you found frustrating to use (or didn't find useful). Why?
14. Tell me about the features of Blackboard that you really enjoyed using (or found useful) (activity stream, communication, grades, calendar).
15. Tell me about the features of Blackboard that you found frustrating to use (or didn't find useful).
16. If you had to sum up your entire experience with the CogBooks in one word, what would it be? Why?

17. What do you think was the biggest factor that affected how you viewed CogBooks?
18. Tell me about the resources in the course (such as PowerPoint slides and mini lectures, and optional activities that were created by the professor) that you really enjoyed using (or found useful). Why?
19. Tell me about the resources in the course (such as PowerPoint slides and mini lectures, and the optional activities, that were created by the professor) that you found frustrating (or not useful). Why?
20. Did you find the information in CogBooks useful? Why?
21. How did you learn to navigate CogBooks? Was it easy to use?
22. What senses did CogBooks appeal to the most? Why?
23. What type of learner do you think you are (visual, auditory, physical, verbal, logical or mathematical, social, solitary)? What do you base this on?
24. Have you ever thought about the type of learner that you think you are? Why or why not? (All of the participants answered this before I asked it in question 21.)
25. Have you every had any kind of assessment that was designed to determine your learning type?
26. Explain your general attitude while you were using CogBooks.
27. Did you find CogBooks restricting? Why?
28. Do you think that CogBooks helped you learn the content? Why or why not?
29. How did CogBooks affect your confidence with the content? How would you describe your confidence with the content?
30. What did you rely on more to learn the content CogBooks or the professor's content? Why?
31. How do you think your usage of CogBooks compares to your peers?

32. How did CogBooks, BB, and the professors' resources combine to help you learn the content?
33. Did CogBooks affect what you thought was important in the course? If so, how?
34. What was your motivation for using CogBooks? Why?
35. Did your interactions with CogBooks affect how you engaged with other portions of the class? If so, how? For example, the mini lectures provided by the professor.
36. Did the first test change how you used CogBooks? Why or why not?
37. How did CogBooks influence how you prepared for exams?
38. Did CogBooks help you understand concepts faster than the other resources? Why?
39. Did your view of CogBooks change over the semester? Why?
40. Do you think that CogBooks made it easier to get through the other assignments? Why?
41. If you had to pick one type of resource (video, reading, cog book assignments, PowerPoints, mini lectures, etc.) that helped you the most in this course, what is it and why?
42. How did you navigate the course content within the individual topics? Did you simply start at the first activity and then move through the others one at a time, or did you use a different strategy? Why?
43. Did you just assume that the professor put assignments and activities into a topic in a particular order for a reason?
44. How important is this course in the overall plans for your future (school, career)? What do you plan on doing?

APPENDIX B: FOLLOW-UP INTERVIEW QUESTIONS

1. Were you able to make in connections with classmates this semester?
2. How did the adaptive courseware affect your relationships with your classmates (how you worked with them, attitudes toward, behaviors with, study groups)?
3. How did the adaptive courseware affect your relationship toward your instructor (how you worked with them, attitudes toward, behaviors with)?
4. If the professor was here and asked how she could improve how she used CogBooks in class what would you tell her? Would your advice change based on whether the course was online or FTF
5. If you had the developers of CogBooks here with us, what would you tell them?
6. How did interacting with the courseware in this class influence your interactions with your peers and instructors in other classes?
7. How would you describe the course environment (or culture maybe)? How did CogBooks help create the overall course environment? Do you think CogBooks could have been used to create a culture
8. Describe your behaviors with CogBooks in this course (how often did log in, how did you manage it, how long did you spend on CogBooks? (Compared to the amount of time you spent on other resources do you think you spent more time on CogBooks than those or not?)
9. What do you think the relationship between your interactions with CogBooks and Blackboard and your performance in the course was?
10. Do you think CogBooks could have been used to create a sense of community in an online course?
11. How much do you think flexibility, convenience, and your own learning needs influenced

how you interacted with CogBooks?

Vita

Ross C. Teller earned his Bachelor of Arts in History, with a minor in English Literature, Cum Laude-Honors from the University of Texas at El Paso in 1998. In 2000, he received his Master of Arts in History degree from UTEP. In 2005, he received his Master of Science in Library Science from the University of North Texas, followed by a Master of Science in Information Systems from Tarleton State University in 2009. In 2016, he joined the Teaching, Learning, and Culture doctoral program within the STEM strand.

Dr. Teller has 21 years of experience in education. He has several Texas State teacher certifications, including Computer Science, Technology Education, Secondary English, Secondary History, Secondary Reading, Principal, and School Librarian. He also has a Legacy Master Technology Teacher certification. He has held a variety of positions at the secondary level, including teacher, librarian, curriculum coach, and instructional technologist.

As an educator, Dr. Teller has stayed at the forefront of instructional technology, providing cutting-edge instruction to students and professional development at both the campus and district level. Most importantly, he was instrumental in the creation of a computer magnet program at a high school. As an instructor in that program, he has taught Computer Science Principles, Full-Stack Web Development, and facilitated the Senior Capstone Project course.

Following graduation, Dr. Teller plans on continuing to work at the secondary level in public education, concentrating on his efforts to improve FTF, online, and hybrid instruction to students. Dr. Teller's dissertation, *Student Learning Behaviors in a Biology Gateway Course: A Mixed Methods Examination of an Adaptive Courseware Environment,* was supervised by Dr. William Robertson.

This dissertation was typed by Ross C. Teller.