STUDENT USE OF A LEARNING MANAGEMENT SYSTEM FOR GROUP PROJECTS: A CASE STUDY INVESTIGATING INTERACTION, COLLABORATION, AND KNOWLEDGE CONSTRUCTION

by

Steven D. Lonn

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Education)
in The University of Michigan
2009

Doctoral Committee:

Assistant Professor Christopher L. Quintana, Chair
Professor Carey Addison Stone III
Associate Professor Eric L. Dey
Research Associate Professor Stephanie D. Teasley

ACKNOWLEDGEMENTS

Completion of this dissertation and my doctoral studies as a whole would not have been possible without the support and guidance of numerous individuals. Without their help, I would not have been able to finish this long, very interesting journey.

I would like to first thank my dissertation committee chair, Chris Quintana, and committee members Eric Dey, Addison Stone, and Stephanie Teasley for their investments of time and energy into the development of my dissertation, for sharing their expertise, and for their suggestions for improvement throughout this process. I would like to particularly thank Stephanie for her guidance outside of the dissertation process and for guiding my scholarly interest in learning management systems (LMS).

Thanks also to the instructor of the case study course for inviting me into his classroom and participating in this interdisciplinary research project. I also want to thank all of the students in the course who participated in my dissertation research and shared their work, thoughts, and feedback about LMS, biology, and technology in general.

I would also like to thank several staff members who work with CTools for their support, mentorship, and encouragement over the past several years. In particular, I would like to acknowledge Sean DeMonner, Diana Perpich, and Jeff Ziegler. I have also valued the support and friendship offered by my School of Education colleagues - we all made it!

Acknowledgement is also due to the many advisors and opportunities that I have had during my graduate career at Michigan. In particular, thanks to Rodney Williams and Jere Johnston, who provided me with guidance, funding, and valuable research and teaching experiences. Also thanks to the University of Michigan School of Education and the Horace H. Rackham School of Graduate Studies for providing funding to conferences and for research as well as access to resources that enabled me to pursue my graduate degrees.

Beyond the support offered through my experiences at Michigan, I want to thank the support from my awesome network of friends and family. To my friends, although you may not have always understood what I was talking about or why it was taking me so long to finish and graduate, you were always supportive and offered an evening or afternoon of relaxation, good food, and watching our kids grow before our eyes. To my in-laws, Hilary and Bruce, as well as their family, Elaine, Jeff, Andy, Drake, and Logan, thank you so much for making me part of your family, your endless love and support, and for helping me to find a new home in Michigan.

There are not enough words to express all of the love, appreciation, and thanks that I feel for my parents, Howard and Sally, and for all of the encouragement you have given me throughout this process, even though we all still don't know exactly what I'm going to be when I grow up! And to my sisters, Tracey and Jennifer, thank you for always having something loving and supporting to offer. Although you are all thousands of miles away, you're always close to my heart. You keep me motivated to persevere and finish what I have started, although the journey may be treacherous, daunting, and seemingly never-ending.

Lastly, I am ever grateful for the love and unending support of my wife, Jackie, and son, Ryan. Jackie, thank you for understanding the crazy life of a graduate student, for doing more than your share of household duties when deadlines were near, and always offering encouragement and a positive outlook, even when the outcome was not what I had intended. Ryan, you are amazing and always seem to find some way to brighten my day with the simplest smile or laugh. I cannot wait to share my tales of this journey as your mother and I watch you grow. I love you both so much, and words cannot do complete justice to express my joy and gratitude for your presence in my life.

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LIST OF ABBREVIATIONS

Analysis of Variance	ANOVA
Computer-Supported Collaborative Learning	CSCL
Computer-Supported Intentional Learning Environment	CSILE
Course Management System	CMS
Electronic Networks for Interaction	ENFI
Global Learning and Observations to Benefit the Environment	GLOBE
The Inquiry Learning Forum	ILF
Learning Management System	LMS
Learning Through Collaborative Visualization	CoVis
Molecular, Cellular, Developmental Biology	MCDB
National Institutes of Health	NIH
Teacher Professional Development Institute	Tapped-In
Undergraduate Library	UGLi

ABSTRACT

Web-based Learning Management Systems (LMS) allow instructors and students to share instructional materials, make class announcements, submit and return course assignments, and communicate with each other online. Previous LMS-related research has focused on how these systems deliver and manage instructional content with little concern for how students' constructivist learning can be encouraged and facilitated. This study investigated how students use LMS to interact, collaborate, and construct knowledge within the context of a group project but without mediation by the instructor.

The setting for this case study was students' use in one upper-level biology course of the local LMS within the context of a course-related group project, a mock National Institutes of Health grant proposal. Twenty-one groups (82 students) voluntarily elected to use the LMS, representing two-thirds of all students in the course. Students' peer-to-peer messages within the LMS, event logs, online surveys, focus group interviews, and instructor interviews were used in order to answer the study's overarching research question.

The results indicate that students successfully used the LMS to interact and, to a significant extent, collaborate, but there was very little evidence of knowledge construction using the LMS technology. It is possible that the ease and availability of face-to-face meetings as well as problems and limitations with the technology were factors that influenced whether students' online basic interaction could be further distinguished as collaboration or knowledge construction. Despite these limitations, students found several tools and functions of the LMS useful for their online peer interaction and completion of their course project. Additionally, LMS designers and implementers are urged to consider previous literature on computer-supported collaborative learning environments in order to better facilitate independent group projects within these systems. Further research is needed to identify the best types of

scaffolds and overall technological improvements in order to provide support for online collaboration and knowledge construction.

CHAPTER 1

INTRODUCTION

Technology-enabled peer interaction is increasingly important and pervasive in higher education. Web-based systems such as Learning Management Systems (LMS) allow instructors and students to share instructional materials, make class announcements, submit and return course assignments, and communicate with each other online using "an integrated set of web-based tools for learning and course management" (Malikowski, Thompson, & Theis, 2007, p. 150). A 2007 report showed that over 90% of all responding American universities and colleges have established one or more LMS-type products for student and faculty use (Hawkins & Rudy, 2008).

LMS are a type of software designed to deliver, track, and manage training and education. Through their development, these systems have been called Course Management Systems (CMS), Virtual Learning Environments, Collaborative Learning Environments, and a host of other monikers. The software is similar in functionality, despite its name, and typically includes methods to manage users, role, and course information, online communication, grading, and web-based or blended delivery of content. Within the spectrum of these systems, there are popular commercial products such as Blackboard (www.blackboard.com), institutionally developed products such as Angel (Penn State, http://ais.its.psu.edu/angel), and open source products such as Moodle (http://moodle.org) and Sakai (www.sakaiproject.org). Since their inception, other software, such as electronic portfolios, have built upon LMS-related innovations and applied them to more specific contexts (e.g., medical school students). Although LMS are increasingly seen as mission-critical applications for teaching and learning (Salaway, Caruso, & Nelson, 2008), very little is known about when, how, or even if these systems promote or are able to "manage" student learning (Koszalka & Ganesan, 2004).

Although most LMS are used for the distribution, management, and retrieval of course materials (Hanson & Robson, 2004), these systems can also incorporate functionality that supports interaction between students and instructors and among students (West, Waddoups, & Graham, 2007) to provide opportunities for enabling institutional innovations in learning and education (Dutton, Cheong, & Park, 2003). Increasingly LMS are providing tools for the kinds of active online engagement embraced by today's generation of students (e.g., discussion tools, chat rooms, wikis, and blogs). Rather than direct transmission of knowledge models of learning that often fail to engage and motivate learners, the tools within LMS provide opportunities for using these systems according to constructivist approaches that encourage students to build their own understandings of the world (Papastergiou, 2006). Specifically, LMS may help ignite a shift from "the transmission of information towards the management and facilitation of student learning" (Coaldrake & Stedman, 1999, p. 7). The focus of this dissertation study is therefore focused on how students used the LMS technology to accomplish their collective goals and objectives as well as if, and how, the LMS technology afforded students the ability to socially construct new knowledge.

1.0.1 LMS as a Facilitator for Peer Interaction, Collaboration, and Knowledge Construction

LMS technology allows individuals to share materials, but also communicate with one another via a wide variety of modalities. Communication, or interaction among students is a key element of the learning process (Palloff & Pratt, 1999; 2007). Online interaction has been a major focus of computer-supported collaborative learning (CSCL) researchers. CSCL is an emerging branch of the learning sciences that is "concerned with studying how people can learn together with the help of computers" (Stahl, Koschmann, & Suthers, 2006, p. 409). CSCL researchers have demonstrated the value of peer interactions and elaborated many of the conditions under which students can use technology to profit from working together (e.g., Dillenbourg, 1999; Stahl, 2002). However, interaction does not simply "happen" in learning environments like LMS and must be intentionally designed (Liaw & Huang, 2000) and can be difficult to sustain (Barron, 2003). Nevertheless, providing students with the opportunity to engage with each other using virtual workspaces is considered valuable not only for learning, but also for preparing students for the increasingly global, knowledge-based economy (Partnership for 21st Century Skills, 2005). Thus it becomes increasingly important for educators to build opportunities for student peer interaction into their curriculum *and* to provide students with the tools for interacting, collaborating, and constructing new knowledge.

In order to study how LMS can facilitate student peer interaction, this dissertation study investigated how students in one upper-level biology course used the local LMS to work together within the context of a course-related group project, a mock National Institutes of Health (NIH) grant proposal. In addition to regular course sites, the institution's implementation of the Sakai Open Source LMS allows any faculty, staff, or student the ability to create "project sites" that extend the online tool set available in course sites and allow student-generated, student-subscribed, student-customized sites with permissions set for more openness and collaboration among the site participants. Project site tools include those for file management, but also tools for synchronous and asynchronous communication to support the gathering, exchanging, and shaping of ideas (Teasley, Rader, Morgaine, Angell, & Narvid, 2006).

In a previous pilot study about student-created project sites, the majority (70%) of the sites were created for group work pertaining to course-related projects (Teasley & Lonn, 2007). Students were creating project sites for group projects and for student-led study groups (coined "eTeam" by Dutton et al., 2003), and to support their learning activities taking place outside of the classroom and outside of course websites. Survey results indicated that the LMS tools students value most for collaboration are file management and asynchronous communication tools, yet they do not solely rely on online tools, using face-to-face and telephone communication to interact and collaborate as well. Overall, this pilot study helped demonstrate that students value the use of project sites for course-related projects, although the pilot study was not able to fully explain *how* students used the various tools with the LMS to interact, collaborate, or construct knowledge. Furthermore, it is not clear from this pilot study whether this application of

LMS technology only effectively helps students manage their projects logistically or also helps students organize and think about their learning opportunities and related processes. This dissertation study fills some of the knowledge gaps illuminated by the pilot study and further investigates how and why students use LMS for their group projects.

1.1 Statement of the Problem and Purpose of the Study

While there has been a significant amount of research on online synchronous and asynchronous communication tools (see De Wever, Schellens, Valcke, & Van Keer, 2006), there has been very little research on how students use the collection of online tools found within LMS to interact, collaborate, construct knowledge, and arrive at common goals (e.g., a group presentation, paper, or other project) with their peers. Since LMS are already being used in nearly every institution of higher education, both in the U.S. (Hawkins & Rudy, 2008) and in Europe (Browne, Jenkins, & Walker, 2006), it is important to understand how students use these systems not only within the context of courses where student peer interaction is mediated by the instructor, but also when students, without direct instructor guidance, are encouraged to use these systems to interact with each other. Through their peer interactions, students may potentially use LMS to collaborate and build new understandings together.

For the purposes of this dissertation study, students' basic interaction, collaboration, and knowledge construction are defined in terms of the social processes that students use to communicate and work together in service of their group projects. The online messages posted on the LMS as well as students' perceptions and opinions of their use of the LMS are used as evidence of these processes. As the definitions below will clarify, collaboration and knowledge construction are specific forms of social discourse of the more general construct of peer interaction.

Basic interaction can be defined as "sustained, two-way communication among two or more persons" (Garrison, 1993, p. 16). The context of these communications may include virtually any topic whether directly related to a goal or objective or not (Northrup, 2001). Based on the research described above as well as how others have discussed this concept (e.g., Gilbert & Moore, 1998; Stuart, 2004), **basic interaction is**

defined, for this dissertation study, as any kind of communication that takes place online within a LMS tool. Since any message posted by one participant within a LMS site can be accessed and read by any other participant, all online messages posted in a LMS site are considered as a type of basic interaction in this study. Furthermore, while there may have been interaction between students and/or the instructor outside of the LMS environment, such interaction is beyond the scope of this study except for students' and the instructors' general perceptions and opinions about such non-LMS interaction.

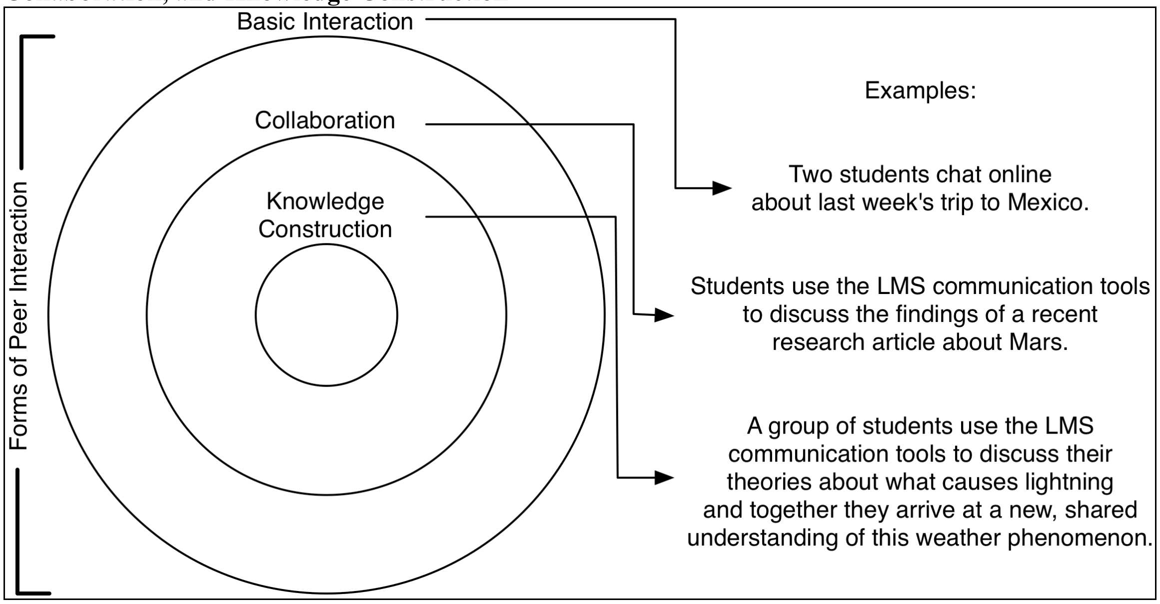
Collaboration is often defined as "a coordinated … activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995, p. 70). Group members collectively negotiate the final outcome or deliverable product of this coordinated activity (Dillenbourg, 1999). While all collaboration between individuals is a specific form of peer interaction, not all interactions between individuals are necessarily concerned with collaborative endeavors (see Figure 1). For example, three students may discuss a recent sporting event, which is a good example of basic interaction, but only when the students begin to interact about a problem, outcome, or deliverable product is the peer interaction also distinguished as collaboration. In other words, only when the group members begin "doing something" related to the central task at hand does the basic interaction between them become collaborative (Dillenbourg, 1999, p. 9). Based on the research described above as well as how others have discussed this concept (e.g., Hathorn & Ingram, 2002; Jonassen, 1999; Stacey, 2005), **basic interaction is further distinguished as collaboration in this dissertation study when students engage in interaction that serves to develop and/or sustain shared ideas about a collective problem within a LMS tool.** One common "problem" across all groups was developing the mock NIH grant proposal. Using this definition of collaboration, interactions that reference more organizational tasks such as face-to-face meetings and LMS site management are not typically included as examples of collaboration.

Based on principles of social constructivism, knowledge construction refers to the types of social interactions with other people that allow individuals to build their understanding about the world (Vygotsky, 1978). Just as not all peer interaction is collaborative, not all collaborations automatically lead to knowledge creation (see Figure

1); the collaborators must engage in conversation in which participants' viewpoints are articulated, accommodated, and challenged by group members in order to construct new meanings (Murphy, 2004). Further, these new meanings must be retained and are "measured by the elicitation of new knowledge or by the improvement of problem-solving performance" (Dillenbourg, 1999, p. 4). For example, two students may be discussing the concept of cell mitosis in which the more experienced student is explaining how this concept relates to their project about cloning. However, the following week, the less experienced student is unable to state how cell mitosis should be discussed in their project paper. Thus, the less experienced student engaged in collaborative discourse with his group member, but was not able to construct new knowledge from this previous interaction. Based on the research described above as well as how others have discussed this concept (e.g., Brown, Collins, & Duguid, 1989; Pea, 1993; White & Fredericksen, 1998), **knowledge construction is defined, for this dissertation study, as collaboration between students within a LMS tool when either new information is conveyed from one student to another and retained by the receiving student or a new understanding is elicited by students through their collaborative interactions.** This definition is for socially constructed knowledge through peer interactions and does not cover other sources for knowledge construction or learning, of which there are many different varieties (e.g., learning new information from a book).

Given the definitions described above, I have graphically displayed the concepts of basic interaction, collaboration, and knowledge construction (see Figure 1). In this diagram, all communication within LMS project sites is considered basic interaction and then, depending on the group discourse processes, can also be considered collaboration and knowledge construction, depending on the contents of the interactive messages. As stated above, all three of these concepts are forms of peer interaction.

Figure 1: Diagram of Forms of Peer Interaction and Relationship Between Basic Interaction, Collaboration, and Knowledge Construction



1.1.1 Research Questions

The overall research question driving this investigation is: How do students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project? In order to answer this research question, I employed several sub-questions to guide the data collection and analysis:

A. What types of peer interactions between students take place within LMS?
B. Which tools do students elect to use to interact within LMS and why?
C. Within the LMS, how often do students' peer interactions occur over time?
D. What factors influence whether students' basic interactions within LMS can be characterized as collaborative?
E. What factors influence whether student collaboration within LMS, if any, can be characterized as knowledge construction?

The sub-questions listed above help explain specific areas and components of the overall research question. By investigating the types of peer interactions, I will be able to determine if the basic interaction between students within the LMS was collaborative and, if so, could any of these collaborations be further characterized as knowledge construction. The sub-question about tools is designed to identify specific features and functions of the LMS and how their design may influence students' peer interactions.

The information about how often students' peer interactions occurred will help explain if different student groups interacted in different ways and also how features of the LMS may have facilitated basic interaction, collaboration, and knowledge construction differently over time (e.g., Was there a higher amount of messages in one LMS tool over another or at one time over another?). Furthermore, some student groups may have very little basic interaction at the beginning of the term and then more regular basic interaction along with greater collaboration and knowledge construction as the project progressed.

Finally, there are a variety of possible factors, both within the LMS and outside the LMS that may influence whether students' basic interactions are collaborative and whether student collaboration leads to knowledge construction. Salomon, Perkins and Globerson (1991) state that there is a whole "cloud of correlated variables" including technology, activity, goal, setting, teacher's role, and culture that can affect how students use and learn with technology (p. 8). Therefore, the study will examine a variety of possible factors, including perception of the LMS itself, the amount of face-to-face group meetings, and collegiality between group members.

The focus of this investigation is not the effects *of* students' use of LMS, or how students' peer interactions or learning changed as a result of using LMS. Rather, I am interested in the effects of students' use *with* LMS or how they interact and learn from each other while using this technology (Salomon et al., 1991). Additionally, this study may illuminate ways to better scaffold learning in these types of online environments beyond making group work more efficient. Thus, I examined how students used LMS project sites and how LMS tools shaped the nature of their basic interaction, collaboration, and self-directed knowledge construction experiences with their peers. In order to complete this investigation, I evaluated students' online communications, data logs from within the LMS, student attitude and perception surveys, student focus group interviews, and the instructor's perceptions in order to fully understand the various uses and factors influencing the use of the LMS that may affect students' peer interaction.

1.1.2 Context

In order to answer the research questions raised in this study, I investigated how students used the local LMS to work together within the context of a course-related group project, a mock NIH grant proposal. Students could complete this assignment alone or in groups of 2-6 students and they could choose any topic related to molecular, cellular, or developmental biology. The instructor's purpose for this assignment was to give students an authentic problem that they will likely encounter as they pursue a career in biology and to allow students the opportunity to apply the knowledge they have accumulated about biology in an area of which they have some interest. This student group project was an excellent fit for my study because of its size and length (students may start working on the assignment in January and it is due at the beginning of April) and because most students chose to work together to achieve a shared product.

1.1.3 Significance

As LMS become ubiquitous in higher education, it is increasingly important to move the focus from faculty use to student use by providing tools that are more fluid, collaborative, and customizable and not simply designed to support traditional hierarchical transmission of knowledge models of learning. By integrating tools for collaborative learning, LMS can provide an environment that will help students to coordinate traditional classroom learning with peer learning. This study builds on previous CSCL research as well as the growing literature on learning management systems, which has previously concentrated on course contexts and instructor-student interactions. Future research will be able to build on this study's detailed investigation of student LMS use within a single course and explore use in other disciplines and at multiple institutions. Furthermore, results from this study will provide empirical support for guiding design recommendations for improving the capabilities of LMS software to better accommodate student peer learning and other group-oriented uses of these systems.

1.2 Overview of the Dissertation

In this chapter, I provided a rationale for the need of this study and I introduced the concepts of basic interaction, collaboration, and knowledge construction that will be used throughout this dissertation. I also introduced the research question and related sub-questions, the context, and the significance of this study. In Chapter 2, I will discuss the social constructivist theoretical framework in which this study is situated, as well as learning and collaborative environments that have utilized the concepts within this framework. I will also review literature on how scholars collaborate as well as research on learning management systems. I will describe the study context in detail and discuss the methodology I followed to construct the study findings in Chapter 3. Specifically, the various data sources will be described as well as participation of those data sources and how the data was analyzed. In Chapter 4, I will present the findings for each research sub-question from the different data sources. Finally, in Chapter 5, I will provide analysis of the results, suggest design improvements for LMS, and discuss some of the limitations and implications of this study. I will conclude with a discussion of future research possibilities that can build on this study's investigation of how LMS can support students' interaction, collaboration, and knowledge construction within the context of course-related group projects.

CHAPTER 2

LITERATURE REVIEW

The following literature review situates this dissertation study in a social constructivist theoretical framework informed by literature that describes collaboration and interaction in computer-supported collaborative learning. I chose this framework because I believe that the theories of social constructivism best explain the kinds of communication and potential learning that LMS is capable of supporting. This literature review is divided into four sections. First, I briefly review literature on interaction and collaboration theories as well as reviewing foundational literature on social constructivism and related theories of distributed intelligence and situated cognition. In the second section, I review how these concepts have been translated into student learning environments and collaborative environments for practitioners. The third section is concerned with how scholars collaborate. Finally, I review the research on learning management systems, focusing on studies that illustrate user preferences for features of LMS that manage course materials and information and how LMS is used for interactive teaching and learning, concluding in a review of recommendations that relate back to interaction, collaboration, and social constructivist theories. I also review literature explaining the underlying intent of learning management system design and how those designs relate to the theories that ground this dissertation study. Finally, this literature review will illuminate how this study fills a missing piece in the LMS literature: investigating how students' use of LMS, as currently designed, may facilitate peer interaction, collaboration, and knowledge construction.

2.1 Theoretical Perspectives on Collaborative Learning

2.1.1 Interaction

This study is grounded in the theories of collaborative learning in which students gain new insight from each other and from shared knowledge building experiences. The first and most fundamental stage of this learning process is interaction between students. Gilbert and Moore (1998) describe interaction as two-way communication among two or more people within a learning context, with the purposes of either task/instructional competition or social relationship building. In addition to simple communication, "interaction should involve complex activities by the learners, such as engaging and reflecting, annotating, questioning, answering, pacing, elaborating, discussing, inquiring, problem-solving, linking, constructing, analyzing, evaluating, and synthesizing" (Liaw & Huang, 2000, p. 43). Interactive discussion encourages what Barnes (1993) describes as "exploratory talk" where students think at multiple levels, use dynamic cognitive strategies (e.g., thinking aloud, clarifying and elaborating the material, etc.), problem solve and are exposed to varying points of view. As students engage in interactive discussion, they bring their own individual "interpretive and interactive needs, beliefs, and patterns that interplay with those of their peers" (Stuart, 2004, p. 57).

In order to analyze student interaction in web-based courses, Northrup (2001) divided student interaction into two main categories: content interaction and social interaction. Content interaction is any activity that is focused on the course content. Social interaction helps students learn about their peers and also combats the isolation and frustration of an individual student that are common hazards in web-based courses. In blended courses that have both face-to-face and online components, the concern about isolation is dramatically reduced. However, social interaction is still important because its very nature lends learners the opportunity to engage in interaction about content (Gilbert & Moore, 1998; Liaw & Huang, 2000).

While Northrup (2001) used two categories to describe student interaction, M. G. Moore and Kearsley (1996) argued that interaction within educational contexts can usually be extended into three categories: learner-content interaction, learner-instructor interaction, and learner-learner (or peer) interaction. Learner-content interaction refers to the interaction that a student has with the subject matter that is presented for study by the instructor or other students. Recent technological innovations that have expanded this type of interaction include text-based forms of content as well as audio and video recordings, computer software, and a variety of interactive multimedia technologies. Learner-instructor interaction includes demonstrating skills, modeling attitudes and values, and coaching students on how to interact with content. Through their interaction with students, instructors attempt to first stimulate the learners' interest followed by helping the student to organize the application of the content. This form of interaction can also include counsel, support, and encouragement to each learner. Finally, learner-learner (or peer) interaction refers to any two-way communication among two or more students with or without the presence of an instructor. Students learn to interact with one another as they negotiate meaning from text and control their own learning in peer-led discussions (O'Flahavan, 1989). Peer interactions are "extremely valuable as a way of helping students to think out the content that has been presented and to test it in exchanges with their peers" (M. G. Moore & Kearsley, 1996, p. 132). Peer interactions were thus very important to investigate in this dissertation, although it was also necessary to ask students about their use of the LMS tools as each tool type (e.g., synchronous vs. asynchronous) may have directly influenced the peer interaction that occurred online.

2.1.2 Collaboration

In order to more fully understand how students used this technology to complete their grant proposal assignment, I also needed to examine how their online peer interaction could be further specified. Rochelle and Teasley (1995) define collaboration as "a coordinated … activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (p. 70). While interactivity can involve complex activities, collaboration is unlikely to occur by simply placing students into groups (Hathorn & Ingram, 2002). When teams of people collaborate, or work together to solve and understand problems, learning and co-construction of knowledge can occur (Jonassen, 1999). In this study, collaboration refers to the "social context that the group process facilitates" (Stacey, 2005, p. 151) in which group members collectively negotiate the final outcome or deliverable product of the collaboration (Dillenbourg, 1999).

Within the computer-supported collaborative learning literature, there is a clear distinction between collaboration and cooperation. "In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work 'together' " (Dillenbourg, 1999, p. 8). In collaboration, learners are also responsible for their own learning as well as for the achievement of their peers (Abrami & Bures, 1996). If learners are solely dependent on other students for their performance or if learners cooperate with others only to enhance their own achievement, collaborative learning is not taking place, according to computer-supported collaborative learning theorists (e.g., Resta & Laferrière, 2007). In this dissertation study, there was no evidence that students were splitting their work without collaborative editing of the final product. Instead, the content of the peer message units indicates that students were indeed collaboratively working together.

Collaboration is most effective when student groups have a common goal, incentives to collaborate, and some degree of independence from the instructor (Hathorn & Ingram, 2002). In this dissertation study, the NIH grant proposal assignment meets all three of these criteria: students must work together to achieve the goal of submitting the final proposal paper, their incentive is a substantial portion of their final course grade, and the instructor has no contact with the group as they work towards their goal, unless they choose to interact with the instructor for assistance.

2.1.3 Social Constructivism

In this study, I was interested not only in students' online peer interactions and collaboration, but also in examining whether these social exchanges led to the kinds of peer learning and newly created understanding between students discussed in the social constructivism literature. At the root of social constructivism is the idea that interactions with other people allow individuals to construct knowledge about the world (Vygotsky, 1978). Vygotsky introduced the idea of a Zone of Proximal Development, the distance between a person’s current level of comprehension and the level that can be achieved through the interaction of individuals with different levels of expertise. Thus, by engaging in social discourse, people gradually advance their own levels of understanding (Kanuka & Anderson, 1998). Within this social interaction, individuals must engage in conversation in which participants' viewpoints are articulated, accommodated, and challenged by group members in order to construct new meanings (Murphy, 2004). Further, these new meanings must be retained and are "measured by the elicitation of new knowledge or by the improvement of problem-solving performance" (Dillenbourg, 1999, p. 4).

Social constructivists also believe that interaction between individuals requires support and guidance if the conversation and activities are to result in increased knowledge. Scaffolding is a "process that enables a child or novice to solve a problem, carry out a task, or achieve a goal which would beyond his unassisted efforts" (Wood, Bruner, & Ross, 1976, p. 90). A teacher, knowledgeable other, or tool can provide the scaffolding. Over time, the scaffolding fades away so that the individuals are in full control of their own learning (Soloway, Guzdial, & Hay, 1994). Quintana and colleagues (2004) suggest that technology software should provide scaffolds and reminders to facilitate productive planning and monitoring of reflective practice. Reflective practices can help learners identify deficiencies in cognition, improve understanding, and identify the characteristics of good performance in a domain (White & Frederiksen, 1998). This type of reflection can promote knowledge building for both individuals and groups of learners (Scardamalia & Bereiter, 1991). One outcome of this dissertation study is to identify what kinds of scaffolds might improve student interaction by encouraging students' collaboration and knowledge construction as they use learning management systems.

2.1.4 Distributed Intelligence

So far in this literature review, I have described theories that discuss how individuals learn and construct knowledge through their social interaction and collaboration with other individuals. Distributed intelligence, however, posits that intellectual acuity is dispersed among individuals, tools, situations, and symbolic and physical environments (Pea, 1993). All of these available resources then come together and collectively shape and direct the activity of the individual.

Distributed intelligence theorists believe that when people use a tool, they are accessing and using the intelligence embodied in the tool itself. Vygotsky (1978) also discussed the power of tools, stating that they serve "as the conductor of human influence" and that their use helps learners internalize, or know how, to complete external activities (p. 55). For example, if a student in geometry uses the Pythagorean theorem to solve a problem about triangles, the students' intelligence and Pythagoras' intelligence (built into the theorem), as well as the intelligence of the school environment (e.g., problem-solving assignments) are collectively used to reach the solution and the student, over time, internalizes the knowledge of the theorem and can apply it to future problems and scenarios.

In computer and Internet environments, a designer can embed supports that can explicitly help the learner understand what features of the environment or tool are salient (Norman, 1990). The design of an object determines how accessible the affordances, the functional properties that determine how an object or tool can be used, are to the user. In a learning environment, an object or a tool with explicit, easily accessible affordances allows a learner to join and contribute to the distributed intelligence in a given activity. In this dissertation study, I explored the affordances designed into a learning management system and will also discuss new ways that additional supports can be provided to users working on collaborative projects.

2.1.5 Situated Cognition

While instructors may acknowledge that knowledge construction is a social endeavor and that the knowledge that students are constructing for themselves may be distributed across people, tools, situations, and environments, they may still separate the acquisition of formal concepts ("knowing what") from the practice of that concept ("knowing how"). Instead of separating these types of knowledge, some theorists believe that the activity and situations in which a concept is developed and used are integral for learning and cognition (Brown et al., 1989). Thus, learning and cognition are situated in activity.

Authentic activities are critical to achieve meaningful learning and cognition. The "meaning and purpose" of these activities "are socially constructed through negotiations among present and past members" of the community within the domain (Brown et al., 1989, p. 34). Learning experiences situated in real-world contexts have a far greater potential to be meaningful for the student and to be retained into the future (Bednar, Cunningham, Duffy, & Perry, 1992). With careful and deliberate structuring of the activity, learners can access the culture of practitioners and gain experience within the domain. For example, Collins, Brown, and Newman (1989) used the term cognitive apprenticeship to describe the practice of students' enculturation into authentic practices. Cognitive apprenticeship begins with a task embedded in an activity familiar to the students, such that they can use their implicit understanding of the task to build toward authentic activity. In the second phase, students are encouraged to deconstruct rules and formulas, and to discover that they are not absolute and depend on context and situation. Finally, students are encouraged to generate their own solutions and thus become creative members of a community of practice. Cognitive apprenticeship thus serves to enculturate students into the culture of the specific domain so that they can fully participate in authentic practices. In this study, the students are assigned a term project in which they write a NIH grant proposal, similar to the work of practicing biologists. This assignment is then considered an authentic activity in which students have to construct knowledge about biology through their social interactions. Students are required in this assignment to utilize the prior knowledge distributed among group members in order to arrive at new, collaborative understandings of biology, evidenced in a final product.

Throughout this section, I have reviewed different theories about how students interact and collaborate about a shared problem that they can discuss and work on through peer-to-peer exchanges. In this study, I investigated how students work together and talk about a group project by using the interactive technologies within a LMS to work towards their common goal of completing a mock NIH grant proposal. Furthermore, I was also interested to see if students, through their interactions in this authentic activity, were able to socially construct new knowledge and understandings of biological concepts. I was also interested in what affordances the LMS provided for students' knowledge creation and to see if any features or perceived problems with the technology inhibited such activities to consider how they can be rectified in future systems. Throughout the analysis of the data collected in this study (see Chapter 5), I use the theories described in this section to guide my understanding of how and why students used the LMS to complete their course project.

2.2 Examples of Social Constructivist Learning Environments

In the previous section, I reviewed literature from the computer-supported collaborative learning perspectives on interaction and collaboration and also reviewed key literature about social constructivism and related theories of distributed intelligence and situated cognition. In the following section, I provide a series of examples of how the theories described in the literature have been used to design various learning environments. First, I review a collection of learning environments that facilitate social constructive activities using computers and other learning technologies, particularly those environments I believe best reflect the ideas presented in the theories of social constructivism, distributed intelligence, and situated cognition. In the second part of this section, I narrow my focus to Internet-based collaborative environments designed for practitioners that provide an online space for individuals to interact, collaborate, and build knowledge with each other. All of these environments have similar tools that are designed to easily allow users to share their knowledge and expertise. These technological affordances are also similar to the types of tools found within learning management systems and thus it is important to understand how users in other learning and collaborative environments have used them to interact, collaborate, and construct new knowledge.

2.2.1 Learning Environments Informed by Social Constructivism, Distributed Intelligence, and Situated Cognition

Since the invention of the personal computer, there have been thousands of different learning environments created to help students communicate and possibly learn from each other. In this section, I have chosen to discuss the environments that I believe best reflect the ideas presented in the theories of social constructivism, distributed intelligence, and situated cognition. One of the first environments to support this form of learning was created at Gallaudet University, the United States' premier higher education institution designed for deaf and hard-of-hearing students, to help improve deaf students' English writing skills through student group interaction. The environment, Electronic Networks For Interaction (ENFI), allowed students and instructors to communicate with each other using networked computers, introducing students to the idea of writing with a "voice" and writing with an audience in mind (Stine, 1989). Instructors typically brought writing samples to a networked classroom and, through the computer network, students would discuss and engage in a discussion about writing while the instructor moderated and guided the conversation. ENFI encouraged "freer student expression with less focus on the teacher" to the extent that system designers suspected that "it allow(ed) the new ideas of social learning to be tested out" (Batson, 1988, p. 7). Overall, the ENFI project was designed to support collaborative meaning-making by providing new ways for textual communication (Stahl et al., 2006). ENFI was one of the first learning environments to effectively use the theories of social constructivism in order to teach students English through their interaction in which differing viewpoints were articulated, accommodated, and challenged by the deaf students and their teachers in order to construct new meanings.

An example of a learning environment that uses distributed intelligence as part of its framework is the Learning Through Collaborative Visualization (CoVis) Project (Pea, Edelson, & Gomez, 1994). In this environment, students collaboratively investigate atmospheric and environmental science through inquiry-based activities. The authentic tools provided use scientific visualization technology and are the same research tools that scientists use in the field. The intelligence in CoVis is distributed between the user, other students, mentors, the research tools, and the learning technology environment itself. In order to access this distributed network of intelligence, students use a variety of asynchronous communication tools. For example, the Collaboratory Notebook allows students to record their activities, observations, and hypotheses, scaffolding their scientific inquiry (Edelson, Gordin, & Pea, 1999). Other students and instructors can then access the Collaboratory Notebook and provide feedback and suggestions, engaging the student in activities that help construct a shared knowledge base among students within the CoVis environment. Overall, the CoVis environment exemplifies the theory of distributed intelligence in that students can collaborate with other students and mentors about their investigations in atmospheric and environmental science and use the knowledge recorded within the system in order to solve future inquiry-based problems and scenarios.

While CoVis does enable students to effectively investigate atmospheric and environmental science in a distributed intelligence environment, situated cognition theorists might point out that the activities within the environment are not authentic and thus are less likely to be meaningful for the student learner. By contrast, some learning environments are structured in order to partner students with practitioners instead of with classmates or the instructor. Through their partnership, students are able to participate in authentic research activities that help students gain experience in a particular domain. For example, the Global Learning and Observations to Benefit the Environment (GLOBE) program allows students to take scientific measurements of their area's airborne particulate counts and cloud cover that are used by scientists and students around the world for environmental research (Finarelli, 1998). Starting in 1992 under the advisement of then Senator Al Gore, GLOBE now includes partners from nearly 9,000 U.S. schools and 4,000 schools from 100 other countries (D. M. Butler & MacGregor, 2003). GLOBE emphasizes an active partnership between scientists and students around the world; students take observations only if there is a research team somewhere prepared to use the data for publishable results. In order for students to share their findings with scientists and other students, GLOBE has a central server for students to report their data online as well as sophisticated visualization and modeling tools available to help students complete their own scientific analysis. There are several communication tools including a web chat interface as well as private messaging between GLOBE schools. Also, online resources including articles uploaded by participating scientists and links to other sources of environmental data and information are provided for students. Overall, GLOBE helps students learn about basic science, mathematics, and geography while participating in authentic science research. Thus, GLOBE is one example of an environment that successfully employs the ideas of situated cognition where students are immersed in collaborative learning opportunities with other students, as well as with real scientists who engage students in authentic activities that enculturate those students into the domain and culture of environmental science.

Very few learning environments using networked computers have effectively combined the ideas and theories of social constructivism, distributed intelligence, and situated cognition. Designed based on the notion that young students can and should be treated as junior scholars (at a minimum), the Computer-Supported Intentional Learning Environment (CSILE) allows students to share their writing with classmates and other students around the world (Scardamalia, 1989; Scardamalia & Bereiter, 1994). I believe that the design and affordances built into CSILE effectively combine the different theories described in the first section of this literature review. For example, as students use CSILE to add, reflect, and comment on other students' contributions within the shared database, the knowledge is added for all students, distributed electronically. Within this database, students may contribute "notes" that describe their questions, learning plans, and current knowledge. Through online threaded discussion with other students and professionals (similar to threaded discussion tools found in learning management systems), the note is refined and revised. Students can thus collaborate in ways similar to those in scholarly disciplines and by working together, they can learn from others' knowledge and can then extend or move beyond that knowledge (Scardamalia & Bereiter, 1991). Students often learn more when given tools to discuss and explain their own ideas and to develop and refine documents in a group (Vosniadou, 1994). The strength of CSILE (or the second generation known as Knowledge Forum) is that the environment "objectifies the knowledge of the community (of student learners) and (encourages) advancement of that knowledge (via) a social collaborative activity. All questions, theories, ideas, information, and discoveries are preserved on the database for the analysis of the entire online community" (Hung, Chen, & Tan, 2003, p. 33). This preservation feature reflects the idea in situated cognition that learning experiences can be retained and used for future students (Bednar et al., 1992). CSILE thus exemplifies several of the theories described above by allowing students to contribute (collaboration) and use the knowledge spread throughout the online database (distributed intelligence) to construct their own understanding and conceptions of authentic problems and assignments (situated cognition) both individually and with other students in their home classroom (social constructivism). All of the learning environments presented in this section facilitate social constructive activities, reflecting many of the theories of social constructivism, distributed intelligence, and situated cognition.

2.2.2 Collaborative Environments for Practitioners Informed by Social Constructivist Theories

In the second part of this section, I describe Internet-based collaborative environments designed for practitioners that are also informed by social constructivist theories. While many of these environments refer to their members as an online community, I refrain from using the term community to describe student groups using LMS because "too little of the education literature provides a clear criteria for what does and does not constitute community; the term is too often employed as a slogan rather than as an analytical category" (Barab, Kling, & Gray, 2004, p. 3). Regardless of the terminology used, these environments relate to the social constructivist theories described earlier in this literature review and provide an online space for individuals to interact, collaborate, and build knowledge with each other.

Teachers are often isolated and removed from interaction and collaboration with other practitioners outside of their school building. The Teacher Professional Development Institute (Tapped-In) was originally conceived in 1997 as a virtual conference center where a diverse collection of educators could come together as a community of practice (Schlager & Schank, 1997). Today, Tapped-In is thought of as a "crossroads" of multiple educational communities where members seek out ideas and colleagues outside of their local practice and forge new relationships among education practitioners, providers, and researchers from around the world (Schlager & Fusco, 2004). The environment features a diverse threaded discussion board that provides teachers with frequent access to experts as well as ongoing peer support. For example, a pre-service teacher can engage in discourse with more experienced teachers about a particular concept, or current teachers can connect with other educators with different views and perspectives. Following the theory of distributed cognition, groups of teachers can draw on and incorporate each other's expertise to create new insights into teaching and learning (Putnam & Borko, 2000). Tapped-In also provides each user with the opportunity to create a virtual office equipped with whiteboards, notepads, file storage space, overhead slides, and URL linking to external resources. These tools can help teachers collaborate with their colleagues, share instructional techniques, "and build a professional culture that focuses collective energy on student learning" (Loucks-Horsley & Matsumoto, 1999, p. 264). By "providing simple collaboration tools and continuous support," Tapped-In has become a prime example of an "effective, sustainable catalyst for teacher learning, collaboration, and innovation" (Schlager, Fusco, & Schank, 2002, p. 151). Therefore, Tapped-In exemplifies many of the theories described earlier in this literature review including distributed intelligence among many different teachers and constructing new knowledge within the situated activity of improving teachers' individual practice.

While Tapped-In is designed to allow any teacher to collaborate and learn from other teachers, some online environments are tailored to instructors in specific domains. Designed to support in-service and pre-service mathematics and science educators virtually, the Inquiry Learning Forum (ILF) helps teachers observe, share, improve, reflect, discuss, and create learner-centered classrooms (Barab, MaKinster, Moore, Cunningham, & The ILF Design Team, 2001). Using an online metaphor of a school, there are several "rooms" of interest for participating educators, foremost of which are the "Classrooms" that enable users to view several video segments of a specific classroom lesson as well as supporting materials including reflective commentary from the teachers, descriptions of teaching activity, lesson plans, student examples, and connections to state and national standards. ILF designers include videos to "provide a vehicle for discussing practice and advancing community as well as individual understanding" (J. A. Moore & Barab, 2002, p. 45). These video segments and supporting materials allow users to review practice quickly and easily, consider multiple perspectives, and examine classroom events with more complexity than written cases (Lampert & Ball, 1998; Putnam & Borko, 2000). As teachers interact with each other around the video examples or a shared topic of interest, they engage in thinking about their own teaching practice and thus make their own tacit knowledge explicit to others (Brown & Duguid, 1991). The other "room" of interest within ILF is the "Collaboratory," an online space in which groups of teachers can come together and discuss a particular class, workshop, pedagogical issue, curricular content, etc. These groups of teachers, or "Inquiry Circles," collaboratively share ideas and resources and interact about their particular topic using a private discussion board (Barab, MaKinster, & Scheckler, 2004). ILF also provides a "Lounge" for general asynchronous discussions around mathematics and science, a "Library" of teaching resource materials, standards, state initiatives, and other materials, an "Inquiry Lab" containing a series of professional development activities, and "My Desk" where each user can store files, bookmarks to external resources, and write in an online journal that can be emailed to any other user. These various tools and the scaffolds for social constructivism within them exemplify some of the types of scaffolds that I will discuss later in this dissertation as a possible way to improve the design of LMS (see Chapter 5). By inquiring about classroom video examples and shared topics of interest, teachers can collaborate about their practice using the technology tools provided within ILF. The classroom video examples act as an authentic activity as described by situated cognition theorists, while the other affordances within ILF provide scaffolds and tools for teachers to communicate and collaborate about mathematics and science practice. Through the tools and activities within this environment, teachers are able to construct new knowledge and insight about their practice.

While the two environments above were designed primarily for teachers, The Math Forum was designed to be a place where all of the mathematics knowledge distributed around the world might be shared among all interested students, teachers, mathematicians, and others. The Math Forum is an interactive and inquiry-informed digital library for mathematics education that brings over two million teachers, students, researchers, programmers, mathematicians, and others together each week to pose and seek solutions to problems (Renninger & Shumar, 2002; 2004). Two of the most popular sections of The Math Forum are the Problem of the Week and Ask Dr. Math. The Problem of the Week is divided into four areas (math fundamentals, pre-algebra, algebra, and geometry) and each week, teachers may use these problems in their classrooms; students may also attempt to solve the problems on their own or utilize the communication tools on The Math Forum website to ask available mentors for help in solving a problem. Past Problems of the Week are available in a digital library online. Ask Dr. Math is a mentoring service (versus a homework help or ready-answer service) in which volunteer mentors help teachers and students think about math and assist the question asker in solving their question, scaffolding their mathematical understanding by illuminating mistakes or incorrect thinking along the way (Renninger & Shumar, 2002). Additionally, emerging from teachers' questions submitted to Ask Dr. Math, a new service entitled Teacher2Teacher was created so that teachers could ask volunteer mentor teachers about philosophies of math learning, pedagogical issues, specific questions about particular curricula or resources, and professional development. All users may also engage in collaborative discussions with other Math Forum users via roundtable discussions about specific math instructional issues. Utilizing the knowledge and expertise distributed amongst its members, The Math Forum is successfully "fostering interactions and contributions that increase opportunities for individuals to work together to think, do, and learn mathematics" (Renninger & Shumar, 2004, p. 204). This environment therefore successfully utilizes the theories of distributed intelligence by connecting teachers, students, researchers, and mathematicians, situated cognition in the authentic activity of solving the Problem of the Week, and providing ways for all of the users to socially construct new understandings of mathematics.

The learning and collaborative environments described in this section of the literature review exemplify the theories I described earlier, particularly those concerned with socially constructing new knowledge. Each of these environments utilizes technological tools in order to realize the potential of these theories. For example, distributed intelligence is collected and shared in peer-to-peer notes in ENFI and CSILE, a Collaboratory Notebook in CoVis, and in Inquiry Circles in the Inquiry Learning Forum. Overall, there are striking similarities across all of these environments including authentic activities that serve to ground the users and enculturate them into a shared collaborative space, tools to share and build the expertise that each user brings into the environment, and technological affordances and scaffolds to help users interact, collaborate, and socially construct new knowledge.

2.3 Review of Collaborative Activities in Scholarly Research

While this dissertation study is concerned with the case of a single undergraduate biology course and how the students in that course used project sites to interact, collaborate, and construct knowledge, it is my intention to discuss how this one case might be applied to disciplines and technologies beyond the ones described in this study. In order to begin to assess the applicability of the findings of this study for other disciplines, it is necessary to review disciplinary norms of collaboration, focusing on higher education and scholarly publications.

The origin of collaboration between scholars likely began in the seventeenth century and was closely connected with the origins of modern science and with professionalization's early stages (Beaver & Rosen, 1978a). Astronomy, where professionalization was the most advanced, had several instances of collaborative work in the late 1600s. There were sporadic increases in collaborative activity in science during the eighteenth and nineteenth centuries followed by a significant increase at the beginning of the twentieth century (Beaver & Rosen, 1978b).

Biglan (1973a) defined three dimensions of academic subject matter: 1) "hard-soft" or the paradigms that distinguish sciences, engineering, and agriculture from social sciences, education, and humanities, 2) "pure-applied" or concern with the application to practical problems, and 3) "life-nonlife" or concern with life systems. These dimensions have been subsequently affirmed by a number of researchers and considered to be a valid conceptual framework for studying academic disciplines (Stoecker, 1993).

Biglan (1973b) argued that scholars in "hard" disciplines have higher rates of connectedness, report more sources of influence on their research goals, and have more coauthors on research publications. Thus, "hard" sciences are highly collaborative while the "soft" (social) sciences generally have lower rates of collaborative scholarship (Bayer & Smart, 1991). Since the "hard" science disciplines often share accepted paradigms (Kuhn, 1970), the nature of the research in those fields may explain the greater rates of collaboration (Endersby, 1996). In sum, "the sciences have a tradition of collaborative projects and, thus, seem to value such research more than other disciplines where collaborative research is not very common or does not have as long a tradition" (Hafernik, Messerschmitt & Vandrick, 1997, p. 31).

In the late twentieth and early twenty-first centuries, collaboration and co-authorship have escalated rapidly, particularly in science, but in other disciplines as well (Palmer & Cragin, 2008). This increase may be a result of one or more of the benefits of collaborative research. Wray (2006) found that collaborative papers are generally of a higher quality, as indicated by citation frequency. He also argued that some discoveries are only possible collaboratively using knowledge that no single researcher is apt to have.

While research problems and questions are increasingly complex, requiring scholarly specialization, division of research labor, and hence, collaboration, such collaborative efforts have not yet changed the reward mechanisms within scientific communities and higher education (Laudel, 2001). Furthermore, there are a variety of disadvantages to collaboration such as the possibility of confused arguments, increased costs of organization and communication, and difficulty when accounting for problems in collaborative research (Hudson, 1996; Wray, 2006). Despite these potential disadvantages, a majority of scholarly researchers acknowledge that "collaborations are a necessary feature of much, though by no means all, contemporary scientific research" (Cronin, 2001, p. 560).

The significant increase of collaborative activity in scientific scholarship at the beginning of the twentieth century (Beaver & Rosen, 1978b) led to a state where the majority of scholarly papers in "hard" sciences have multiple authorship and the number of credited authors continues to increase to the point where single authorship is relatively uncommon, particularly in the physical sciences (Endersby, 1996). In contrast, in the humanities, sole authorship continues to dominate, although scholars do consult and collaborate with others while writing (Palmer & Cragin, 2008). The social sciences are left in the middle between the two extremes of science, where collaboration is normal and expected, and the humanities, where collaborative work is rare.

In both "hard" and "soft" sciences, collaborative work continues to gain prominence and acceptance within the collective disciplines. Contemporary conceptions of collaboration deemphasize knowledge *within* the discipline and instead stress knowledge *between* disciplines and their scholars (Brew, 2008, emphasis added). Today, a majority of researchers subscribe to the following view:

> By extending the circle of researchers, we broaden the perspectives and add voices to the field. Exploring issues of mutual interest by doing collaborative work is not only personally and professionally enriching but also benefits the field as a whole (Hafernik et al., 1997, p. 31).

This "circle of researchers" is of such significant size in present-day literature that I feel confident in arguing that the study presented in this dissertation will be of interest to an audience that extends far beyond those interested only in the intersection of undergraduate biology and technology. Just as scholars in social sciences and even some in humanities have begun to recognize, value, and use the advantages of collaboration in their research, this study will be of interest to anyone who is attracted to evidence of technology-assisted interaction, collaboration and knowledge construction.

2.4 Review of LMS-Related Literature & Relation to Theoretical Framework

In this final section of the literature review, I review the research on learning management systems (LMS). First, I describe a selection of research that either focused on or revealed user preferences for features of LMS that manage course materials and information. Next, I present literature that addresses how LMS is used for interactive teaching and learning. I also review LMS recommendations that relate back to interaction, collaboration, and social constructivist ideals. I conclude by illuminating how this dissertation study fills a missing piece in the LMS literature: investigating how students' use of LMS, as currently designed, may facilitate interaction, collaboration, and knowledge construction.

2.4.1 Management of Materials and Information for Courses

Learning management systems have a variety of tools available for instructors to use in service of their instruction and interaction with students. The activities fostered by these tools can be categorized as management of materials and information or interactive teaching and learning opportunities (Lonn & Teasley, 2009). I first present LMS literature that either focused on or revealed user preferences for activities concerned with managing course materials and information.

In a formative assessment of the homegrown TeLeTOP LMS at the University of Twente (Maslowski, Visscher, & Collis, 2000), researchers collected data from 25 courses and found that the most popular functions of the TeLeTOP system included managing files, particularly PowerPoint slide handouts. Similar results were found in an online survey of 57 faculty members using WebCT at several universities in Switzerland (Holm, Röllinghoff, & Ninck, 2003). In an examination of perceived usefulness, instructors reported that they valued the content module (file management) and threaded discussion tool the most and the chat tool the least. The authors argued that it is not the LMS tool *per se* that is useful or not useful, but rather the way the tool is used in a given course and if the tool helps instructors and/or students achieve the desired course goals. The reader is left to conclude that the Swiss instructors' course goals were largely concerned with materials management.

Hanson and Robson (2004) studied the use of WebCT and Blackboard at three US colleges (Williams, Brandeis, and Wesleyan) to determine: 1) if instructors and students perceived a learning value from using LMS, 2) what web-based processes provided the most learning benefit, and 3) if views differed between instructors and students. When asked to select the benefits of LMS, both instructors and students chose "saves time" more often than "improves learning." Features that supported making class information and readings available online were most highly valued. With respect to learning benefits, instructors highly valued online discussions while students responded favorably about LMS features that allowed online access to grades, sample quizzes, and audiovisual review materials, all of which were seen as having strong learning benefits by students.

This theme of LMS benefiting time savings over learning improvement has been found in other studies as well. For example, in a 2003 survey of 172 faculty members at Colorado State University, Yohon, Zimmerman, and Keeler (2004) found that significantly more WebCT adopters than non-adopters reported that technology, in general, saved them time on their daily tasks and enabled them to improve their teaching.

Of these adopters, instructors were found to use content publishing tools the most, while interactive tools such as chat and threaded discussion were seldom used.

In a recent study, researchers investigated student and faculty perceptions at a large public university about learning through PowerPoint and WebCT (Parker, Bianchi & Cheah, 2008). While the faculty viewed LMS as a means to connect students with each other and themselves, students did not perceive LMS as a way to increase their connections with others and did not recognize the technology as a vehicle for social networking. Researchers found that the typical use of LMS was as a repository for course materials and argued that such use is unlikely to increase student learning for those students who prefer problem-based learning activities.

The studies presented above demonstrate that instructors and students have a strong affinity for the ability to share course-related materials and manage course information using LMS. If management of course materials is the initial draw to LMS, perhaps instructors can be persuaded to begin using the interactive tools once they have adopted LMS for materials and information management. For example, while Herse and Lee (2005) found that the students they surveyed believed that lecture notes and handouts were the most valuable aspect of using LMS, the authors argued that LMS "can be used as a catalyst for (instructors') self-reflection and to help facilitate change from passive to active learning" (p. 51). In the next section, I present literature that illustrates how some instructors and students used the interactive features of LMS to guide and foster student interaction and collaboration.

2.4.2 Interactive Teaching and Learning Activities in LMS

While the management of course materials and information is an important function of LMS in higher education, I believe that there is potential for more interactive teaching and learning within LMS in the spirit of the social constructivist theories presented earlier in this literature review. I therefore present key examples from the LMS literature below that review how these systems are used for interactive teaching and learning activities.

Bridging from the literature that illustrated how users preferred management aspects of LMS, two studies illustrate that while users begin with distributing and retrieving course materials, there is potential for more interactive uses for teaching and learning. First, a frequently cited study surveyed 740 faculty and instructional staff across the 15 institutions of the University of Wisconsin system (G. Morgan, 2003). Researchers found that instructors adopt LMS principally to manage administrative and relatively mundane tasks associated with teaching, particularly in large lecture courses. The faculty also used the system to achieve a number of teaching goals that included supplementing lecture materials, increasing transparency and feedback, and increasing contact with and among students. In the process of using the various LMS tools, many instructors reported that they began to rethink and restructure their courses and ultimately their teaching resulting in a kind of "accidental pedagogy." However, McGee, Carmean, & Jafari (2005) argued that as LMS design develops and interacts with other available technologies, LMS tools have the potential to directly impact teaching and learning without depending on "accidents."

In a similar, but more recent study, West et al. (2007) conducted interviews and surveys about how instructors at Brigham Young University implemented Blackboard into their instruction. Using Rogers' (2003) model for understanding the adoption decision process, they found that instructors grapple with several small decisions as they weigh the advantages and disadvantages in each stage of their adoption. Although West and his colleagues found that most instructors used Blackboard for the distribution, management and retrieval of course materials, the authors note that LMS are increasingly incorporating functionality (e.g., discussion boards, synchronous chat, etc.) that supports communication between students and instructors and among students. Both the West et al. (2007) and G. Morgan (2003) studies illustrate that while instructors initially prefer management aspects of LMS, they begin to use more of the interactive features for their teaching as they gain familiarity with the technology.

Many of the examples of instructors using LMS for interactive teaching and learning activities come from case studies where the faculty member is interested in utilizing the affordances of the technology to increase student collaboration and learning. For instance, Gaensler (2004) investigated the use of WebCT in an undergraduate precalculus class and found that students' learning was both active and collaborative. Students also exhibited reflective discussion and integration of new ideas with pre-existing knowledge. As the instructor used various features of the LMS, including email, discussion boards, online lecture notes, and interactive quizzes, students gained confidence in engaging in dialogs that enhanced their understanding of pre-calculus concepts. Gaensler argued that this blended approach engendered a more profound learning experience than if the course had only been taught in a traditional face-to-face instructivist approach.

Topper (2003) investigated the relationship of his students' level of participation and their subsequent sense of learning and instructional quality in a graduate-level online course using the Blackboard LMS. The instructor found that students posted online messages, but the online discussion did not mirror the deep connected conversations he was used to in face-to-face contexts. Over time, the instructor realized that he had to find an alternative to his pedagogy for facilitating face-to-face discussions. Instead of immediately inserting himself in the conversation, which was typical for the instructor in face-to-face discussions, he instead found that in online discussions, he had to allow students to interact and communicate among themselves before asserting his control or authority in the conversation. The majority of students in this course responded that they learned as much in the online class as they would have face-to-face. This case illustrates that an instructor cannot simply transfer their existing face-to-face practice into an online setting within a LMS but must instead modify their instructional approach in order to maximize the potential of the online tools and successfully guide students' learning.

In a similar example of how LMS can foster pedagogical change, an instructor at the University of Missouri-Columbia agreed to participate in a WebCT LMS pilot program as he taught his senior seminar (Bender, 2005). Over time and as he taught more courses via WebCT, the instructor began to make a series of pedagogical shifts, including having students participate in online discussion groups and collaborate about the content of their required essays. He found that "instead of focusing on management issues, (LMS) need to focus on a new pedagogy that facilitates group interaction, allows students to control much of what they are learning, and encourages ownership" (p. 112).

Weston (2000) investigated the use of WebCT in a mathematics course for nine pre-service teachers. Throughout the course, the instructor regularly used the threaded discussion board, private email generated from WebCT, and an online quiz tool. Weston did note that students experienced difficulty writing mathematical notations within WebCT's discussion board and the online quizzes. Despite this and other minor weaknesses identified, the instructor was satisfied with his use of LMS and believed that "no other software has been found which contains its versatility and array of tools" for designing, implementing, and teaching his online course.

Instructors at an Australian university examined their own teaching of a distance learning Education course over two years (Dougiamas & Taylor, 2003). In the first year, the instructors noticed that while students did post messages in the online discussion board, they posted messages that did not engender reflection or discussion by other students. In the second year, the instructors used a variety of scaffolds to facilitate reflective dialogue between students, including writing prompts, peer-rating scales for each message post, and instructor-supplied models of the type of messages they thought best led to meaningful discussion between students. Students in this second iteration of the course posted much more reflective messages that led to highly interactive online discussions about various course topics, replicating findings from a similar study (Curtis & Lawson, 2001). As a result of their findings, the instructors hoped to implement LMS design suggestions in order to better scaffold student discussion. This study and the other case studies presented above illustrate how continued LMS use can influence instructors' practices as they learn how to effectively guide student interaction, collaboration, and peer learning using the provided tools.

In some instances, faculty are not only concerned with encouraging students to interact and collaborate using LMS, but also whether students' course achievement improves through LMS use. In one study, instructors at Purdue University used WebCT as an online supplement to their undergraduate geology course (Witham, Krockover, Ridgway, & Zinsmeister, 2002). Using student tracking, a WebCT tool that helps measure students' use of the system, the instructors studied the effectiveness of the LMS environment throughout the semester. Ninety percent of students indicated that this was their first experience using WebCT. The instructors found that students who used the

LMS frequently throughout the semester received average or above-average final course grades while students who did not visit the LMS as frequently received below-average course grades. While students enjoyed using the system and found it convenient and helpful, Witham and colleagues state that it is ultimately the responsibility of the instructor to ensure that the LMS technology is used to benefit learning.

In another study, researchers investigated six weeks of LMS (Moodle) access logs of sixty undergraduate students enrolled in either a statistics or computer science course (Chanchary, Haque & Khalid, 2008). They supplemented the log data with a brief survey in order to obtain demographic and attitudinal data. As in the previous study, students who accessed LMS frequently achieved better course performance than students who had "low" access rates.

Overall, the studies presented in this section of the literature review illustrate that instructors and students can utilize LMS to engage in highly interactive teaching and learning activities. While instructors may initially be drawn to LMS for the management affordances provided, the examples above show how these systems can help instructors modify and adapt their pedagogical approach in order to use the provided tools to guide student interaction and collaborative learning. In the next section, I discuss some recommendations made to modify the existing designs in order to better scaffold student learning opportunities within LMS.

2.4.3 Recommendations for LMS Improvement in the Future

The LMS research studies reviewed above have led to quite a few recommendations for improving or designing new LMS in order to facilitate and scaffold student interaction and collaborative learning. Some of these recommendations also relate to the theories of social constructivism presented earlier in this literature review. Even as LMS were just beginning to become commonplace technology in higher education, Oliver (2001) was already advocating that LMS "should be evaluated on the basis of their ability to support planned learning goals and teaching strategies" (p. 47). Oliver described two main categories of web-based tools: development tools for faculty to create and deliver content online and active learning tools for students to engage in higher-order information processing. He argued that most LMS focus predominantly on content delivery and that instructors should strongly consider using external web-based tools or developing new support structures to promote higher-order learning.

Approaching the discussion of improving LMS from an "Information Age-appropriate paradigm," Watson and Watson (2007) listed a host of recommendations for improving LMS. Among these recommendations, they suggested that LMS should provide more constructivist-based instruction that focuses on flexible, learner-defined goals and then LMS should support collaborative learning in order to extend the learning environment beyond the classroom. Similarly, Wang, Sierra, and Folger (2003) argued that LMS can foster a social constructivist approach in which the lecturer can facilitate students' engagement in peer learning.

In a literature review of LMS-related articles indexed in the Digital Library of the Association for the Advancement of Computing in Education, Papastergiou (2006) found that LMS was used in a variety of courses and disciplines and rated positively by students, yet these systems lacked supports for successful constructivist learning. Specifically, the author suggested that LMS need to improve their assessment design so that faculty can apply various constructivist-based assessment techniques. She further suggested that LMS tools need to better support hands-on tasks and intensive, structured instructor-student and peer interactions on the basis of these tasks. While LMS do provide communication tools such as chat and threaded discussion boards, Papastergiou argued that collaboration and interaction among LMS users needs to be improved "comprising sophisticated facilities such as flexible personnel and shared workspaces, interactive collaborative authoring tools, functional resource sharing tools, and scaffolds for framing online interactions to effectively support online learning communities" (p. 610).

Carmean and Haefner (2002) claimed that LMS "do not provide a pedagogical platform any more than chalk, chairs, and tables provide the classroom learning experience" (p. 28). Instead, they argued that it is incumbent upon the instructor to use the LMS tools provided in ways that encourage a deeper learning experience than simply dumping content into an online shell. These authors claimed that deep learning can occur when learning is social, active, contextual, engaging, and student-oriented. These principles follow constructivist tenants of learning. For example, for contextual learning, Carmean and Haefner suggested that an instructor could require students to take materials and links to external resources and "literally construct their own representations of the new knowledge and share those representations with the instructor or the rest of the class via the digital drop box" (p. 32), echoing the concept of situated cognition in which learning is rooted in activity (Brown et al., 1989).

The LMS-related literature is varied and presents several different perspectives of how instructors and students perceive and use these systems for teaching and learning. In some instances, LMS are used solely for the management of course materials and information. In other cases, instructors learn how to utilize the interactive features of LMS in order to foster peer communication and collaboration. Despite these examples of interactive teaching and learning activities within LMS, some argue that these systems need to be improved so that students can more easily learn from each other and construct new knowledge through their peer interactions. In the final section of this literature review, I illuminate a missing piece in the LMS literature and how my dissertation study attempts to fill it.

2.5 Filling In a Missing Piece in LMS-Related Literature

The purpose of this literature review was to situate this dissertation study in a social constructivist theoretical framework, and also illuminate a missing piece in the LMS-related literature that this study fills: investigating how students' use of LMS, as currently designed, may facilitate students' peer interaction, collaboration, and knowledge construction. In the first section of this literature review, I detailed the theoretical underpinnings for this study, including the concepts of social constructivism and the related theories of distributed intelligence and situated cognition. Then I reviewed how software designers have built computer environments and Internet-based community tools informed by these learning theories. I also reviewed disciplinary differences in patterns of scholarly collaboration in order to illustrate that the findings of this study will be of interest to those outside of the "hard" sciences. Finally, I discussed the research on learning management systems (LMS), focusing on both empirical and survey-based studies and recommendations made to improve LMS design in the future.

What are Learning Management Systems and what are they for? From the reviewed literature, LMS are designed to deliver and manage instructional content, identify and assess individual learning goals, and collect and present data for supervising the learning process (Watson & Watson, 2007). It appears, however, that the vast majority of instructors and students only experience the instructional content portion of these systems (e.g., G. Morgan, 2003; West et al., 2007). Nevertheless, constructivist and active learning ideals are encouraged for future use of LMS (Carmean & Haefner, 2002; Dougiamas & Taylor, 2003; Gaensler, 2004; Herse & Lee, 2005; Oliver, 2001; Papastergiou, 2006). Overall, the majority of research has focused on *what* LMS are and *what* is capable using the technology, but there have been very few studies, if any, that have focused on *how* these systems are used by students in order to support their course-related assignments. This study is therefore designed to fill this gap in the LMS-related literature.

While constructivist learning is encouraged and suggested for the use of LMS (e.g., Oliver, 2001), there are very few studies that have studied how LMS tools, as currently designed, can foster these kinds of learning opportunities in which students collaboratively build new understandings of the world through their social interactions with each other. Those studies that have examined this aspect of LMS use have focused on instructor-student interaction and instructor-mediated peer interaction (e.g., Gaensler, 2004). Even Dutton et al. (2003), who coined the term "eTeam" (virtual student groups for studying or projects), only briefly mentioned student groups' use of LMS and did not investigate how students used LMS tools to interact, collaborate, and construct knowledge around their course project. Recently, Cleary and Marcus-Quinn (2008) conducted a case study on students' use of Sakai project sites at the University of Limerick in Ireland and found that students were generally positive about the LMS for their group projects. Within this case study, students used project sites in order to work and discuss a group project about developing instructional materials for an e-learning course within their Technical Communication course. While the distance learning student groups used more features of the project sites, ultimately most of the students in the case study did not fully utilize the technology as the Sakai implementation was in a pilot phase and students were unforgiving about minor technical glitches. Overall, this case study raised several important suggestions for future research including observing student use of project sites in a longer timeframe (instead of only a month), with a fully functioning version of the software, and with less instructor prescription into the use of the project site features. This dissertation study therefore investigated student use of LMS tools, without instructor mediation, within the context of a course-related project in order to explore how LMS, as currently designed and fully implemented, can foster constructivist learning opportunities for students and how tools might be improved to greater scaffold future student interaction, collaboration, and knowledge construction. In the next chapter, I discuss the research methodology for this dissertation study including a description of the study context, participants, and data sources.

CHAPTER 3

RESEARCH METHODOLOGY

In conducting this study, I sought to understand how learning management systems (LMS) promote or "manage" student learning by examining how students used this technology to interact, collaborate, and construct knowledge with each other within the context of a course-related project. Specifically, I wanted to understand what types of peer interactions took place within the LMS, what tools students elected to use, how often students interacted with each other over the course of the semester, and what factors potentially influenced students' basic interactions being further distinguished as collaborative or knowledge construction. In order to understand these issues in a naturalistic setting, I designed this study to follow the basic tenants of case study research (Merriam, 1998; Yin, 2003). This study relied on a variety of mixed quantitative and qualitative data collection methods such as transcripts of peer-to-peer online messages, LMS event logs, online surveys, and focus group interviews (Creswell, 2008).

In this chapter, I briefly review the overarching research question for this study as well as related sub-questions. Following this review, I describe the setting, and technology studied in this dissertation. Next, I describe the course that was the focus of this research and the participants from this course. For the variety of data sources used to answer the research questions, I first introduce each data source, describe the participants for each source, and also review additional data collection procedures for the study. Finally, I describe the data analysis procedures for each data source.

3.1 Research Questions

The overall research question driving this investigation was: How do students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project? In order to answer this research question, I employed several sub-questions to guide the data collection and analysis:

A. What types of peer interactions between students take place within LMS?
B. Which tools do students elect to use to interact within LMS and why?
C. Within the LMS, how often do students' peer interactions occur over time?
D. What factors influence whether students' basic interactions within LMS can be characterized as collaborative?
E. What factors influence whether student collaboration within LMS, if any, can be characterized as knowledge construction?

3.2 Study Context

3.2.1 University and LMS Context

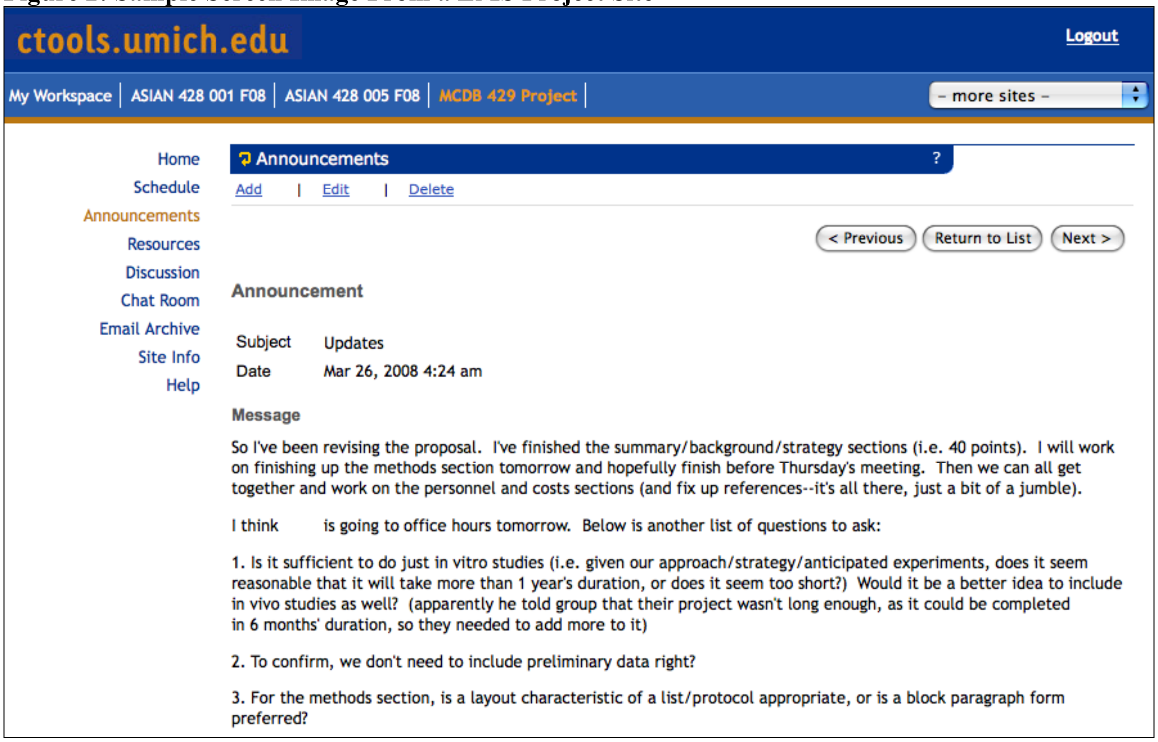
This study was conducted during one winter semester (January-April) at a large, public American Midwestern four-year university with very high research activity and a majority undergraduate enrollment, according to the Carnegie Classification of Institutions of Higher Education (http://www.carnegiefoundation.org/classifications/). The university enrolls approximately 26,000 undergraduate students, 15,000 graduate and professional students, and employs approximately 5,700 faculty members.

The faculty and students at this university have been using a LMS since 1997. The current version of the system, CTools, is built on the Sakai open source architecture (see www.sakaiproject.org). Open source software, like Sakai, refers to a set of principles and practices that promote free access to the design and production of goods and services (The Open Source Initiative, 2006). Approximately 89% of the faculty and 99% of the students have used the LMS for at least one class (Lonn & Teasley, 2008). In the most recent term (Winter 2009), faculty created 4,000 course sites. There are over 19,000 users of the system per day and as many as 9,300 users are logged in at one time. While only faculty can create course sites, all faculty, students, and staff at the university can create a project site and subscribe an unlimited number of members to that site. Over 3,500 project sites were created in the most recent term.

Project sites extend the online tool set available in course sites and allow student-generated, student-subscribed, student-customized sites with permissions set for more openness and collaboration among the site participants. Within this tool set are a variety of communication tools that support either synchronous (occurring at the same time) or asynchronous (not occurring at the same time) peer interaction between site members. A sample screen image from a project site is displayed in Figure 2. Project site owners may elect to use any of the following tools on their project sites:

- **Resources:** File storage space. Any file type may be stored; URLs to other websites may be created, and shared citation lists may be created. Email notifications of new resources may be sent as well.
- **Announcements:** Non-threaded, asynchronous messages for all site participants to read. Email notifications may be sent as well.
- **Chat:** Synchronous conversation tool. All messages are automatically saved and are viewable for all site participants.
- **Discussion:** Threaded, asynchronous messages for all site participants to read.
- **Email Archive:** All email sent via a site-specific email address is delivered to all participants and also saved online for archival and searching.
- **Wiki:** A collaborative document-writing tool. Any site participant may add or modify additional pages and a history of changes is automatically recorded.
- **Schedule:** A shared calendar used to post deadlines, due dates, etc.
- **News:** Allows site participants to view RSS feeds from external sources.
- **Web Content:** Allows site participants to view external websites.

Figure 2: Sample Screen Image From a LMS Project Site



3.2.2 Rationale for CTools as the LMS Context in This Study

CTools, built on the Sakai open source architecture, is a prime example of a learning management system where the majority of instructors and students use the system on a near daily basis for their courses (Lonn & Teasley, 2008). The core functionality of CTools is similar to other LMS (e.g., Blackboard, Moodle, Angel, etc.) in use at nearly every higher education institution around the world (Browne et al., 2006; Hawkins & Rudy, 2008). The core functionality of the Sakai LMS, similar to other LMS, is designed for use to support either face-to-face courses or to conduct courses online where the instructor supplies material, facilitates discussion, and mediates learning activities. However, the added functionality of project sites in the architecture helps distinguish CTools, and other Sakai implementations using this feature, from other LMS that are solely designed to provide an online presence for coursework. Project sites thus represent a new area of research in order to discover how these systems can best facilitate student interaction, collaboration, and knowledge construction.

In this study, I investigate if and how students, without instructor mediation, can use the project site functionality in CTools to interact, collaborate, and learn from each other. However, the project site functionality is not activated in all Sakai implementations and does not exist in any regular fashion in other LMS. Therefore, this study not only shows how students in one course used LMS project sites to collaboratively complete their group project, but also serves as a potentially strong research-based exemplar to other Sakai institutions around the world to activate their project site capabilities as well as advocating other LMS to institute such functionality. Additionally, I discuss how LMS tools can be improved and customized within the context of collaborative projects.

3.2.3 Case Study Course

One course was selected as the case for this study - an upper-division undergraduate laboratory course in the Molecular, Cellular, Developmental Biology (MCDB) department designed to be an intense laboratory experience that provided a survey of current theory and techniques. The instructor has taught this course for eight years. This course was selected after a recruitment period in which I identified courses for which students had created project sites in the past and then contacted the instructors for those courses. The message sent to instructors asked if they were teaching a course in the future that met two desired criteria: 1) The course must have 30-100 students and 2) the course has a group project assignment in which three or more students are required to work collaboratively to deliver a final product (paper, presentation, etc.). After discussing the proposed study with several instructors, the MCDB course was selected for its overall fit with the desired criteria and the objectives of my research study.

As part of the MCDB laboratory course, students completed a term project of writing a mock grant proposal to the National Institutes of Health (NIH) on any unpublished MCDB topic of their choosing. Students worked independently or in self-selected groups of 2-6 students. The goal of this term project was to give students experience in understanding how to sell their research ideas and how to be successful at obtaining the money to accomplish their objectives. Students were required to turn in a grant proposal summary due in early February that included the names of all group members and the groups' hypothesis and general strategy for doing the proposed work. The final grant proposal was due in early April, about three weeks before the end of the semester (see Figure 3). The instructor posted copies of the official NIH grant proposal forms for students to use as scaffolds when writing their mock grant proposals.

3.3 Participants

Overall, there were 32 groups formed and 8 students decided to work independently. Students were not required to use project sites as part of their grant proposal assignment. Twenty-one of the groups (82 students) decided to use the LMS to create their own project site, representing 66% of all the students in the biology course (see Table 1 for a breakdown of group types and sizes). The group size averaged about 4 students per group for the groups that used the LMS and about 3 students for groups that did not.

Table 1: Breakdown of Student Group Sizes by Use of LMS Project Sites

Group Type	1 Student	2 Students	3 Students	4 Students	5 Students	6 Students
Used LMS	None	4 Groups	7 Groups	2 Groups	3 Groups	5 Groups
Did Not Use LMS	8 Students	4 Groups	3 Groups	2 Groups	1 Group	1 Group

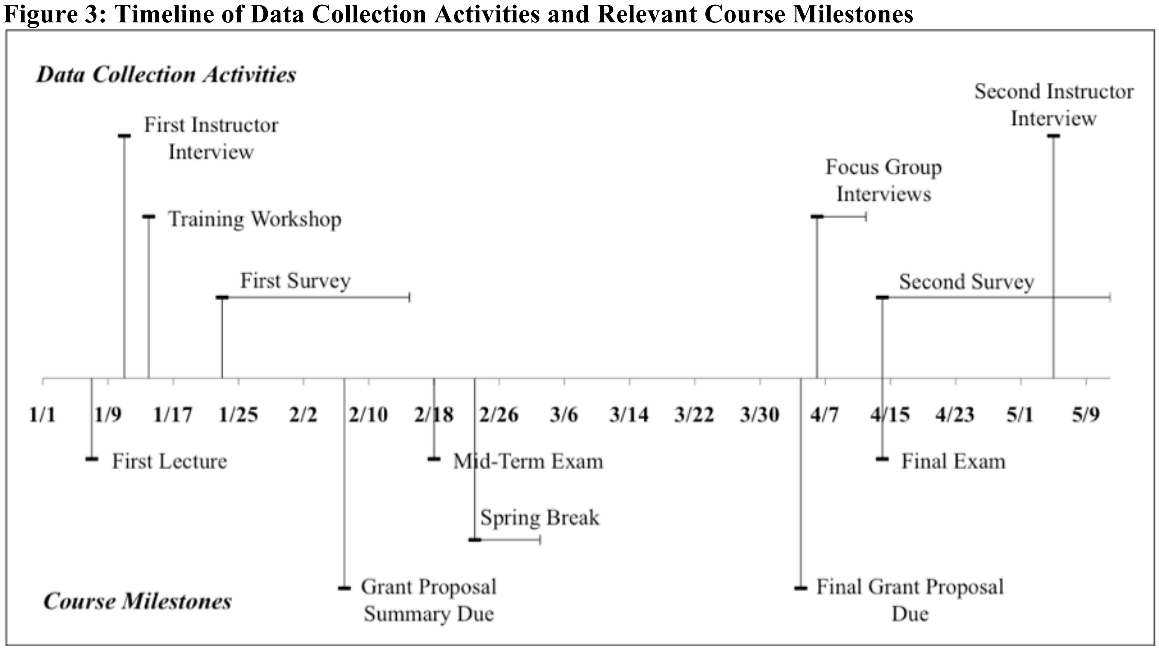
While this study was largely concerned with students who used the LMS project sites in order to work towards the completion of their mock NIH grant proposal assignment, I also included students who did not use the LMS in the sample for the online surveys and also invited these students to participate in the focus group interviews. I decided to include these students in order to gain a wider perspective of why students chose to use the LMS or chose not to use the LMS for their group project. It was also relevant to ask students who did not use the LMS for their group project about their overall impressions of the technology since they used the LMS for their courses.

The overall composition of the MCDB course was 82% senior-level undergraduate students, 9% masters-level graduate students, 6% junior-level undergraduate students, and 3% doctoral-level graduate students. A majority (62%) of the students were male and the majority (51%) of students were in biomedical engineering programs. Many other students (29%) were in MCDB-affiliated programs. For the subset of students who used the LMS project sites, there was very little (1-2%) difference in these demographic variables. Participation rates in the online surveys and focus group interviews are detailed below within the descriptions of each data source.

3.4 Data Collection Sources and Procedures

Quantitative and qualitative data sources were used in this dissertation study to help answer the overall research question and related sub-questions. In this section, I briefly describe the nature of each data source, when the data sources were collected, and any relevant participation information; the analysis procedures for each of these data sources are described below in the data analysis methods section of this chapter. The data sources used in this study include the transcripts of all relevant peer-to-peer computer-mediated communication within the LMS project sites, LMS event log data, online student surveys (administered at the beginning and end of the term), student focus group interviews, and interviews with the instructor. A timeline of data collection activities and relevant milestone dates for the MCDB course is provided below (see Figure 3).

Figure 3: Timeline of Data Collection Activities and Relevant Course Milestones



3.4.1 LMS Peer-to-Peer Message Units

The content of all communication between site participants within the Announcements, Chat, Discussion, and Email Archive tools was collected. These qualitative data consisted of communication messages sent from one student to one or more other group members (e.g., a threaded discussion post, a chat message, etc.). There were a total of 736 Chat messages, 198 Announcements messages, 45 Email Archive messages, and 33 Discussion messages. The peer-to-peer messages were copied to a spreadsheet for analysis. Table 2 shows an example of two rows from this spreadsheet.

Table 2: Example Rows From LMS Peer-to-Peer Message Transcript Spreadsheet

Group ID	Student ID	Date & Time	Tool	Message Unit
PS-C	PC2	3/31 20:11:00	Chat	I've budgeted $290,000 for a principal investigator and two lab techs for 2 years.
PS-L	PL2	3/12 20:49:42	Announcements	Hey guys, here's a reminder to get your background write up done by tomorrow in lab when we will discuss it. Please upload to (the LMS) when you're done, and could one or two person please bring laptops so that we can check for the flow of the ideas and give comments. Thanks:)

3.4.2 LMS Event Log Data

Every user action within the LMS, designated as "meaningful" by the LMS designers, is logged quantitatively in a searchable database. For example, when a user uploads a file, posts a new announcement, or deletes a chat message, each "event" is logged in the database along with some brief reference information (e.g., the URL of the uploaded file). For this study, I analyzed the event logs from each project site in order to understand how different groups and students within those groups used the LMS. All of the log activity from the entire semester (14,298 separate log events) was included in the study and copied to a spreadsheet for analysis. Below is an example of 4 rows from this spreadsheet (see Table 3). In this example, the pres.begin and pres.end events refer to students' login and logout from the LMS project site and the content.read events correspond to files downloaded from the Resources tool.

Table 3: Example Rows From LMS Event Log Spreadsheet

Group ID	Student ID	Date & Time	Event	Tool	Event Reference
PS-D	PD1	4/3 15:15:06	pres.begin	Presence	/presence/4d94631d-90f7-4c7c-0026-d3d054c7531d-presence
PS-D	PD1	4/3 15:15:25	content.read	Resources	/content/group/4d94631d-90f7-4c7c-0026-d3d054c7531d/Hygiene Hypothesis Literature/Final+Grant+Proposal.doc
PS-D	PD1	4/3 15:16:06	content.read	Resources	/content/group/4d94631d-90f7-4c7c-0026-d3d054c7531d/Hygiene Hypothesis Literature/Final+Grant+Proposal.doc
PS-D	PD1	4/3 15:23:47	pres.end	Presence	/presence/4d94631d-90f7-4c7c-0026-d3d054c7531d-presence

3.4.3 Online Student Surveys

Online surveys were administered in order to measure student attitudes, beliefs, and opinions about the LMS, how students used the technology, and how LMS can be improved (see Appendices A & B). Students were also asked about their use of other collaboration technologies, such as instant messaging and websites like Facebook (http://www.facebook.com) as well as students' face-to-face meetings outside of the LMS environment. The survey instrument was partially informed by the pilot project site survey conducted in spring 2007 (Teasley & Lonn, 2007). In order to gauge how students' opinions change throughout the semester, the survey was administered at the beginning and end of the semester.

All students enrolled in the MCDB course were invited to participate in both online surveys. Participants were entered into a random drawing for a $20 electronic gift certificate for each survey. The first online survey was administered between late January and mid-February. The second online survey was administered between mid-April and mid-May (see Figure 3 for placement in timeline). Both of the surveys were administered online, and students were invited via email. Reminder emails were sent approximately once per week while the surveys were available. Fifty-two students (41% response rate) participated in the first survey, and fifty-six students (44% response rate) participated in the second survey. Response rates between 25% and 30% are typical for online surveys with follow-up reminders via email (Cook, Heath & Thompson, 2000; Kaplowitz, Hadlock & Levine, 2004). A breakdown by student group of online survey and focus group participation is presented below (see Tables 4-6).

3.4.4 Student Focus Group Interviews

To get a deeper understanding of the issues raised in the online survey, student groups were invited to share their thoughts and opinions about the LMS in semi-structured focus group interviews (see Appendix C). Students were interviewed in focus groups, as opposed to individually, so that group members could build off of each other's ideas and responses (D. L. Morgan, 1997). Students' self-selected term project groups defined the composition of these focus groups (e.g., all of the students from group PS-M were invited to the same focus group interview). Some of the questions in the focus group interview protocol were replicated from the interview instrument used for the pilot project site research conducted in spring 2007 (Teasley & Lonn, 2007).

Thirty-four students across nine groups, eight of which used LMS project sites, participated in a group interview. Most of these interviews took place in early April, after students turned in their grant proposal assignments but before the MCDB course final exam (see Figure 3 for placement in timeline). Students received a $10 electronic gift certificate for participating in the focus group interviews. A breakdown by student group of online survey and focus group participation is presented below (see Tables 4-6).

Table 4: Participation in Online Surveys and Focus Group Interviews for Student Groups With LMS Project Sites

Group ID	Number of Students	Survey 1	Survey 2	Focus Group Interview
PS-A	6	2	1	
PS-B	3			
PS-C	3	2	2	1
PS-D	6	3	3	5
PS-E	4	3	1	
PS-F	2			
PS-G	3	1	1	
PS-H	5	3	3	
PS-I	3	3	3	3
PS-J	4	3	3	
PS-K	6	1	3	
PS-L	5	1	4	
PS-M	6	3	2	6
PS-N	3	2	3	
PS-O	3	2	3	3
PS-P	6	4	5	6
PS-Q	3	3	3	3
PS-R	2	1	1	
PS-S	2	1		2
PS-T	2	1	1	
PS-U	5	1		
TOTAL	82	40	44	29

Table 5: Participation in Online Surveys and Focus Group Interviews for Student Groups Without LMS Project Sites

Group ID	Number of Students	Survey 1	Survey 2	Focus Group Interview
NS-AA	2	1		
NS-BB	6		2	
NS-CC	2			
NS-DD	4	2	2	
NS-EE	3	3	2	
NS-FF	4			
NS-GG	2	1		
NS-HH	3	1	1	
NS-II	3			
NS-JJ	5	2	1	5
NS-KK	2		1	
TOTAL	36	10	9	5

Table 6: Participation in Surveys for Students Who Worked Alone

Number of Students	Survey 1	Survey 2
8	2	3

3.4.5 Instructor Interviews

Student peer-to-peer interaction can often be encouraged or stymied by the context that the instructor provides for a collaborative project. To better understand the instructors' intent that students work collaboratively and the instructors' approach to technological tools and attitudes toward collaborative knowledge construction, I formally interviewed the instructor at the beginning and end of the semester (see Appendices D & E). The first semi-structured interview gauged the instructor's approach to collaboration and technology, and the second semi-structured interview investigated the instructors' impression of students' work, their use of LMS project sites, and any changes in his attitudes about collaboration and technology. The start-of-term interview took place in early January, and the end-of-term interview took place in early May (see Figure 3 for placement in timeline).

3.4.6 Additional Procedures

In addition to the data collection activities, there were additional procedures that I completed as the researcher. Before the start of the course, I communicated with the instructor, and he included a brief description of my dissertation project in the course guide that was distributed via the course LMS site. At the first lecture of the MCDB course, I introduced myself to the students, described my research project, and distributed consent forms. I also distributed and collected consent forms at subsequent lectures in January.

In mid-January, I offered a training workshop for LMS project sites that about 20 students attended (see Figure 3 for placement in timeline). During this workshop, I demonstrated how to create a project site, add an icon in order to personalize the site, turn on different tools, and use some of the major tools (e.g., Resources, Announcements). Students were provided a two-page handout about basic tips for creating a project site (see Appendix F).

3.5 Data Analysis Methods

In this section of the chapter, I present the methods that were used in order to analyze each data source. All of the data sources were analyzed according to specific methods in order to best answer the sub-questions that guided the data collection and analysis for this study in an effort to answer the main research question: How do students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project? However, not all of the data sources were used to answer every research sub-question. A summary of which data sources were used for each research sub-question is presented below (see Table 7).

Table 7: Research Sub-Questions and Corresponding Data Sources

Research Sub-Question	Peer-to-Peer Message Units	Event Logs	Online Surveys	Focus Group Interviews	Instructor Interviews
A. What types of peer interactions between students take place within LMS?	X		X	X	X
B. Which tools do students elect to use to interact within LMS and why?	X	X	X	X	X
C. Within the LMS, how often do students' peer interactions occur over time?	X	X	X		
D. What factors influence whether students' basic interactions within LMS can be characterized as collaborative?	X	X	X	X	X
E. What factors influence whether student collaboration within LMS, if any, can be characterized as knowledge construction?	X	X		X	

In order to prepare for the data analysis, I created a copy of the course roster and randomly assigned unique identifiers for all students and their groups. The 21 groups that used a LMS project site were assigned a single letter with the prefix PS for "project site" (PS-A through PS-U), the 11 groups not using a project site were assigned a double letter with the prefix NS for "no site" (NS-AA through NS-KK), and the eight students who completed their grant proposal assignment were assigned the label "ALONE." The students within each group were assigned a random number and letter combination corresponding to their group (i.e., PD1 in group PS-D, NEE1 in group NS-EE, ALONE4 for a student working alone). In the following sections, I will explain the specific analysis methods and how each data source was used to answer the relevant research sub-questions.

3.5.1 LMS Peer-to-Peer Message Units

The analysis of the peer-to-peer message units helped answer all of the research sub-questions in this study. These qualitative data helped describe the different types of peer interactions that took place within the LMS, information about the tools those peer interactions occurred within, and when those peer interactions took place throughout the semester. Furthermore, differences between the content of the messages of different peer interaction types were explored to help answer the research sub-questions.

In order to help answer the research sub-questions, the LMS peer-to-peer messages were analyzed in three steps in order to 1) define the individual units of analysis, the message units, 2) code the interaction type of each message unit, and 3) code the topic(s) for each message unit. These steps are explained below.

3.5.1.1 Step One: Defining the Message Units

In order to analyze students' peer-to-peer communication, messages were first combined or separated into individual units, or "units of meaning" based on the natural breaks in students' conversations and messages to each other (Henri, 1992). The natural breaks are defined by the individual researcher, but should strive for consistency within each research study. To achieve this consistency, I followed Henri's guidelines for using the analytical objectives of the research to define the way that the peer-to-peer messages were organized. I primarily focused on Henri's interactive dimension of analysis (e.g., explicit interaction between individuals such as statements or a group of statements that refer to one another). Although I did not have a second rater complete this step of analysis independently, I did explain my reasoning for the separation and/or combination of different messages with a research collaborator, and we adjusted a few (approximately

10) message units based on our discussions and coding of the message units (see Steps 2 and 3 below). This adjustment grew organically out of the series of discussions and work sessions with the research collaborator. This type of procedure is typical in the analysis of computer-mediated communication (Strijbos, Martens, Prins, & Jochems, 2006).

There were several instances when individual messages were combined into one message unit. For example, a group of students was using the Chat tool to discuss the same basic topic of having enough information to turn in their grant proposal summary:

> [PD4]: So do we have enough right now to turn in a rough draft? ….
>
> [PD1]: Yeah I think we do
>
> [PD5]: lol
>
> [PD3]: Well.....we need enough to present a small problem-solution outline

In some instances, a single peer-to-peer message needed to be split into separate message units because a student discussed different ideas within the same message. For example, a student posted an Announcement message in which first, the student discusses the slides for the lab portion of the course and second, the student asks other group members to review the draft for the mock grant proposal. The two portions of the Announcement message were thus split into two separate message units:

> Message Unit 1:
> [PD3]: I posted my slides for the Thin Chromatography lab. I just remembered today that we were presenting tomorrow! (PD1 you are doing the procedure for Developing the Control TLC Plate and Developing a New Solvent System).
>
> Message Unit 2:
> [PD3]: Also, every one please look over our draft of the Grant Proposal and come to class with corrections that you believe need to made. During/after class we can go over what we think needs to be changed.

There were a total of 397 peer-to-peer message units collected from the LMS. The majority (69%) of peer messages were left intact, meaning that one message sent from one individual was considered one message unit. From the Chat tool, 614 individual messages were combined into 79 message units, as described in the first example above. Fifteen Announcement messages, three Discussion posts, and two Email Archive messages were split into multiple message units, as described in the second example above. A breakdown of how message units were defined is provided below in Table 8.

Table 8: Breakdown of LMS Peer-to-Peer Message Unit Definition By LMS Tool

LMS Tool	Number of LMS Messages Treated as Their Own Message Unit	Number of LMS Messages Split Into Multiple Message Units (and Corresponding Number of Message Units)	Number of LMS Messages Combined Into One Message Unit (and Corresponding Number of Message Units)
Announcements	182	15 (34 Message Units)	
Chat	22		614 (79 Message Units)
Discussion	30	3 (6 Message Units)	
Email Archive	39	2 (5 Message Units)	

The analysis used these message units instead of individual words or sentences because "it is useless to attempt an objective determination of the unit of meaning and a lexicological or linguistic definition. For content analysis, the essential factor is not form but meaning" (Ibid, p. 134). Out of the 21 total groups that used LMS sites, 18 groups had at least one peer-to-peer message unit posted. Within these 18 groups, 63 students (out of 75 total students) posted at least one peer-to-peer message unit.

3.5.1.2 Step Two: Coding the Peer Interaction Type

Each message unit was coded in order to classify the type of peer interaction that took place. The message units were coded either as basic interaction, collaboration, or knowledge construction according to the definitions described above in Chapter 1. First, basic interaction is any kind of communication that takes place online within a LMS tool. For example, in the following Announcement message, a student asks the group members when the best time for a face-to-face meeting is to discuss their group project. This message unit is an example of interaction because the student is using the LMS communication tools to communicate with other group members.

> [PU1]: We never decided when we would meet tomorrow. [PU3] says he is free to meet after 6. I'd be fine to meet then as well. Any thoughts? When is everyone available? Also, if we have to meet for a long time, I could try to book a room at the (library) (that might not be necessary for tomorrow, but maybe later on when our meetings get longer).

Second, collaboration is when students engage in peer interaction that serves to develop and/or sustain shared ideas about a collective problem. For example, in the following Discussion post, a student expresses concern that there may be an important difference in types of a serum for their group project. This message unit is an example of collaboration because the student is using the LMS communication tools to actively engage in peer interaction with other students in order to develop a shared idea about a serum for the group project.

> [PC2]: Our written protocol uses fetal calf serum. The vero E6 cell line that I found from ATCC recommends that we use fetal bovine serum. I really don't know the difference but there seems to be one according to ATCC.

Finally, knowledge construction is an extension of collaboration between students when new information is transferred and retained from one student to another or a new understanding is elicited by students through their collaborative interactions. For example, in the following Chat conversation, one student is asking another about what a particular biological procedure measures and whether that procedure is redundant. The second student is sharing biological knowledge and together, the two students are building a shared understanding of this area of biology. This message unit is an example of knowledge construction because [PD4] is trying to convey a new understanding of flow cytometry and cell surface molecules to [PD3] that later communication reveals is retained by [PD3].

> [PD3]: ok...I'm still confused about this flow cytometry thing.....what are we measuring?

> [PD4]: cell surface molecule expression // you bind antibodies labeled with a fluorescent tag to the molecules you want and then when you

drop the cell through a laser beam the tags will emit given wavelengths of light in amounts directly proportional to the amounts of molecules on the surface of the cell

[PD3]: yea i understand that but i am confused because isn't this redundant? aren't the ELISAs telling us this? // or are we doing this as a back-up to ensure we get the correct results? // what does cell surface molecule expression mean?

[PD4]: ELISAs are telling us what molecules are circulating in the blood // flow is telling us what is going on on the cells themselves

[PD3]: what's an example of a cell surface molecule?

[PD4]: cell surface molecule expression means that a cell changes the molecules it displays at its surface differently in response to different stimuli, for example, DCs express more surface CD80 and CD 86 when their TLRs are stimulated

There were two coders for all message units in this step of the coding process generating a high inter-rater reliability, (α = .838, n=252 message units). Following individual coding, the other coder and I discussed the coding discrepancies and mutually agreed on a final peer interaction type code for the disputed message units.

3.5.1.3 Step Three: Coding the Topic(s) of Each Message Unit

While the peer interaction type coding helps show what kinds of interactions took place within the LMS project sites, what students discussed is left unclear. I therefore employed a second type of coding in which the content of the message units was considered. This two-phase qualitative coding method (Bogdan & Biklin, 2003) allows the researcher to first generate a multitude of category codes while considering several questions raised by Berkowitz (1997) that help qualitative researchers think about coding qualitative data. These questions are:

- What patterns and common themes emerge in responses dealing with specific items? How do these patterns (or lack thereof) help to illuminate the broader study question(s)?
- Are there any deviations from these patterns? If yes, are there any factors that might explain these atypical responses?

- What interesting stories emerge from the responses? How can these stories help to illuminate the broader study question(s)?
- Do any of these patterns or findings suggest that additional data may need to be collected? Do any of the study questions need to be revised?
- Do the patterns that emerge corroborate the findings of any corresponding qualitative analyses that have been conducted? If not, what might explain these discrepancies? (p. 4.1)

After coding the topics, I completed a second round of focused coding that eliminated and combined coding categories to arrive at 27 total topic codes (see Table 9). There were a total of 627 topic codes assigned with each of the 397 message units assigned a maximum of three codes. As in Step 2, there were two coders for the topic qualitative coding generating a high inter-rater reliability, (α = .860, n=252 message units). Following individual coding, the other coder and I discussed the coding discrepancies and mutually agreed on the final topic code(s) for the disputed message units.

Table 9: Topic Coding Categories for LMS Peer-to-Peer Message Units

Article Sharing	Group Management	Proposal Topic
Biology Concepts / Procedures	Instructor Feedback	Research
Budget / Pricing	Knowledgeable Other	Resource Management
Confusion	Mice Strains	Sharing of Contact Information
Definition of Terms	Online Meetings	Site Management
Disagreement	Other Course Projects / Assignments	Stem Cells
Division of Labor	Peer Review	Summarizing
Face-to-Face Meetings	Previous Research	Virus Quantification
General Discussion	Proposal Details	Writing

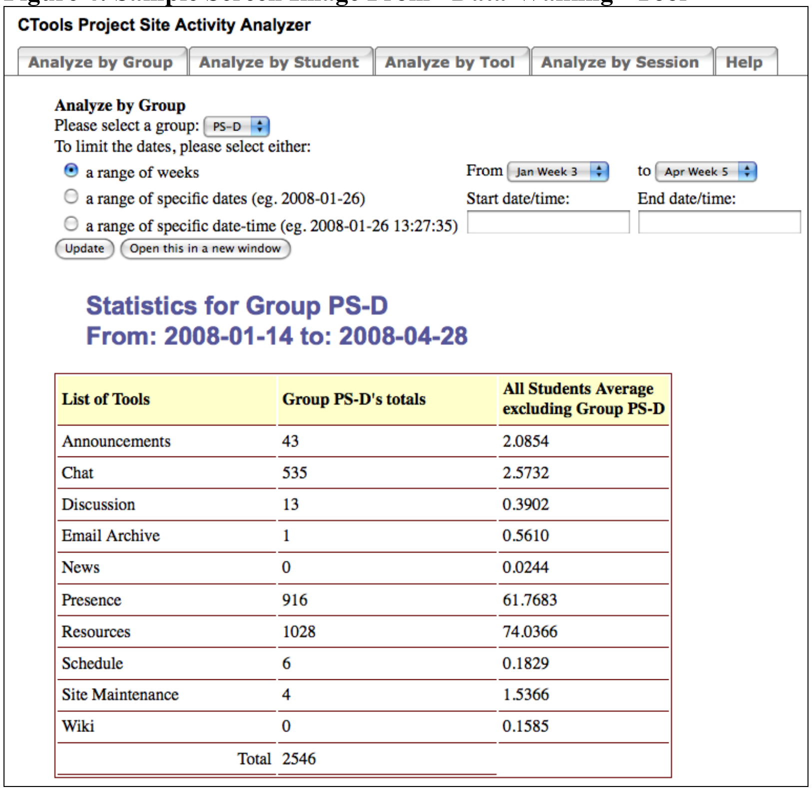
3.5.2 LMS Event Log Data

The data from the event logs were useful for helping answer many of the research sub-questions. Since the event logs record all user actions in every tool, these quantitative data are useful for identifying which tools are used more than others and also how tools are used in different ways over time. Categorization of interactive versus content sharing events was also useful for answering the research sub-questions.

I queried all event log activity for the 21 LMS project sites from the database. For each site, I removed any log events that I may have created when visiting the site so that my activity did not impact the results generated from this data source. I also removed all log events from the initial site setup mechanism that the LMS automatically generates (e.g., an extra Resources event when the directory is first created) again to limit the impact on the generated results. I grouped all events from each week and assigned a field of week of the term (e.g., March Week 2) in order to more easily identify when in the term an event was taking place. I also grouped all of the events from each tool and assigned a corresponding tool field (e.g., Announcements). Finally, I replaced the students' official id with the study ID.

Given the size and scope of the event log data, I needed a way so that I could explore the data from multiple levels and perspectives in order to understand how the logged events helped answer my guiding research questions. I therefore worked with a group of students in a School of Information course about database application design to build a "data-walking" tool that I could use to look at the log data from the tool, group, or student level and instantly compare with other tools, groups, and students (see Figure 4). Using this tool, I was able to investigate the event log data with the research questions acting as a guide for my explorations. For example, research sub-question B asks which LMS tools students used and why. Through this "data-walking" tool, I was able to explore how each LMS tool was used in each student groups' site and quickly compare that use with the mean level of use in other groups. The tool was also instrumental in discovering the types of documents uploaded and accessed in each project site, discussed in the results for sub-question A. Furthermore, the "data-walking" tool allowed me to investigate each student group and explore similarities and differences in each group members' use of the tools from a quantitative perspective, which helped illuminate some possible factors affecting the type of peer interaction, as discussed in the results for sub-questions D and E. Overall, I was able to use the "data-walking" tool to discuss the event logs in a way that provided a descriptive quantitative context to the qualitative data sources collected as part of this study.

Figure 4: Sample Screen Image From "Data-Walking" Tool



CTools Project Site Activity Analyzer

Analyze by Group | Analyze by Student | Analyze by Tool | Analyze by Session | Help

Analyze by Group
Please select a group: PS-D
To limit the dates, please select either:

- a range of weeks — From Jan Week 3 to Apr Week 5
- a range of specific dates (eg. 2008-01-26) — Start date/time: End date/time:
- a range of specific date-time (eg. 2008-01-26 13:27:35)

Update | Open this in a new window

Statistics for Group PS-D
From: 2008-01-14 to: 2008-04-28

List of Tools	Group PS-D's totals	All Students Average excluding Group PS-D
Announcements	43	2.0854
Chat	535	2.5732
Discussion	13	0.3902
Email Archive	1	0.5610
News	0	0.0244
Presence	916	61.7683
Resources	1028	74.0366
Schedule	6	0.1829
Site Maintenance	4	1.5366
Wiki	0	0.1585
Total	2546	

3.5.3 Online Student Surveys

Students' responses in the two online surveys helped answer several of the research sub-questions. Students' perceptions about various online activities, the tools within and external to the LMS, and information provided about frequency of LMS use, face-to-face meetings, how well student groups worked together, and LMS impact on the success of the course project were all critical information.

The online surveys were administered at the beginning and end of the semester (see Figure 3 for placement in the timeline). The two surveys were combined into two spreadsheets, one for quantitative data (i.e., answers to Likert scale and multiple choice items) and one for qualitative data (i.e., answers to open-ended items). Students who did not use the LMS were removed from the analysis of LMS-specific questions. The quantitative data was analyzed using standard statistical tests (e.g., correlations, t-tests) in order to answer the guiding research questions.

The qualitative data were coded using the coding categories developed for the peer-to-peer message units (see Table 9). Only the codes relevant to the context of students' responses in the online surveys were carried over from the message unit analysis. I also added coding categories that emerged from students' responses, arriving at 20 total codes (see Table 10). For example, when students were asked to explain which LMS tool they thought was the most useful for collaboration, I added a code for each LMS tool (e.g., Resources Use) and then used the peer-to-peer message codes to categorize the rest of the message (e.g., Article Sharing).

Table 10: Coding Categories for Qualitative Survey Items

Announcements Use	Efficiency	Peer Review *
Article Sharing *	Email Archive Use	Proposal Details *
Chat Use	Face-to-Face Meetings *	Resources Use
Convenience	Group Management *	Site Management *
Discussion Use	More Personable	Speed
Division of Labor *	More Visual	Writing *
Easier	Organization	

Note: * code carried over from the peer message unit topic analysis (Step 3)

3.5.4 Student Focus Group Interviews

The qualitative data from the student focus group interviews helped answer several of the research sub-questions. Students' explanations and opinions about using the LMS tools for different peer interactions as well as suggestions for improvement helped bolster and explain findings from other data sources as well.

A paid transcriptionist transcribed each of the digitally recorded student focus group and instructor interviews. Since student names were not recorded, it was not possible to individually identify the students in the focus group interviews. I combined portions of the interviews into "units of meaning" based on the natural breaks in interviewees' conversations with me, similar to the method used in the first step of the LMS peer-to-peer message analysis (Henri, 1992). I coded the transcriptions using the coding categories developed for the peer-to-peer message transcripts (see Table 9) and the student survey qualitative answers (see Table 10). Only the codes relevant to the context of students' responses in the focus group interviews were carried over from the previous analyses. I also added coding categories that emerged from students' and the instructor's responses, arriving at 35 total codes (see Table 11).

Table 11: Coding Categories for Student Focus Group Interviews

Accessibility	Explanation	Peer Review *
Announcements Use **	Face-to-Face Meetings *	Potential Use
Budget / Pricing *	General Site Use	Problems with Site
Changing Topic	Group Size	Proposal Topic *
Chat Use **	Hypothesis	Research *
Clarification	Instructor Templates	Resources Use **
Communication	Lack of Site Use	Site Features Insufficient
Conflict	Learning	Suggested Improvement
Difficulty With Site	Notifications	Wiki Use
Discussion Use **	Organization **	Workflow
Division of Labor *	Other Technologies	Writing *
Email	Overwriting Files	

Note: * code carried over from the peer message unit topic analysis (Step 3)
** code carried over from the online survey qualitative analysis

3.5.5 Instructor Interviews

The instructor interviews helped answer several of the research sub-questions. The instructor explained his approach to using his LMS course site and the tools within the LMS as well as the overall context and requirements regarding the mock NIH grant proposal assignment, all of which was helpful when explaining several of the findings from other data sources.

A paid transcriptionist transcribed each of the digitally recorded instructor interviews. I combined portions of the interviews into "units of meaning" based on the natural breaks in the instructor's conversations with me, similar to the method used in the first step of the LMS peer-to-peer message analysis (Henri, 1992). I coded the transcriptions using the coding categories developed for the peer-to-peer message transcripts (see Table 9), the student survey qualitative answers (see Table 10), and the student focus group interviews (see Table 11). Only the codes relevant to the context of the instructor's responses were carried over from the previous analyses. I also added coding categories that emerged from the instructor's responses, arriving at 22 total codes (see Table 12).

Table 12: Coding Categories for Instructor Interviews

Accessibility ***	Future Use	Resources Use **
Announcements Use **	General Site Use ***	Student Effort
Authentic Activities	Group Size ***	Student Feedback
Chat Use **	Instructor Feedback *	Student Success
Communication ***	Instructor Templates ***	Site Features Insufficient ***
Conflict ***	Other Technologies ***	Suggested Improvement ***
Course Context	Proposal Details *	
Experience	Proposal Topic *	

Note: * code carried over from the peer message unit topic analysis (Step 3)
** code carried over from the online survey qualitative analysis
*** code carried over from the student focus group interview analysis

In the next chapter, I present the findings from the various data sources for each guiding research sub-question.

CHAPTER 4

RESULTS

In this chapter, I present the data collected from students' peer-to-peer messages via the learning management system (LMS) project sites, event log data from the LMS, students' responses to two online surveys, student focus group interviews, and interviews with the course instructor. All of these data sources are used to help answer the overall research question driving this dissertation study: How do students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project? This chapter is organized by the sub-questions that help answer the central research question, with data from each source relevant to the sub-question presented in turn.

4.1 Research Sub-Question A: What Types of Peer Interactions Between Students Take Place Within LMS?

As students used the LMS to complete their mock NIH grant proposal, they worked and discussed the project in a variety of different ways. The conversations between students may be characterized as 1) basic interaction, or any kind of communication that takes place online within a LMS tool. Beyond this general definition, student peer interactions may be further distinguished as 2) collaboration, when students engage in peer interaction that serves to develop and/or sustain shared ideas about a collective problem within a LMS tool, or 3) knowledge construction, collaboration within a LMS tool between students when new information is transferred and retained from one student to another or a new understanding is elicited by students through their collaborative interactions. Thus, there are three potential types of peer interactions that may have taken place within students' use of LMS project sites.

In order to answer this research sub-question, I utilized four data sources:

- The peer-to-peer message units were used to identify the different types of peer interaction that took place within the LMS as well as the general topics of the content within these online peer interactions.
- In the online surveys, students were asked about the perceived utility of various activities that relate to different types of peer interactions.
- Students were asked during the focus group interviews about their approach to using the LMS for different types of peer interactions.
- In the start-of-term interview, the instructor described his approach to using his course LMS site, which helps explain how students used their LMS project sites to interact while working on their mock NIH grant proposals.

4.1.1 LMS Peer-to-Peer Message Units

4.1.1.1 Peer Interaction Types

A critical component for identifying the types of peer interaction between students within the LMS project sites, the 397 peer-to-peer message units were identified as basic interaction, collaboration, or knowledge construction (see Table 13). The majority (60%) of message units were identified as collaboration, followed by basic interaction (37%), and knowledge construction (3%). The median number of message units was 11.5 per student group. There was a wide disparity in the number of message units for each student group ranging from 4 units (PS-A) to 120 units (PS-D). Three groups (PS-B, PS-R, PS-T) did not have any message units, meaning that there was no evidence of online peer interaction within the LMS. Also, the breakdown of message units by peer interaction type varied from group to group which was largely dependent on the overall number of message units. For example, group PS-P had 20% of their message units identified as knowledge construction, but this group only had 5 total message units, meaning that 1 message unit was identified as knowledge construction. Groups with over 10 message units were generally more representative of the overall breakdown trend, such as group PS-N which had 30 message units, 10 (33%) of which were identified as basic interaction, 19 (63%) as collaboration and 1 (3%) as knowledge construction. Seven of the ten message units identified as knowledge construction were from one student group: PS-D.

Table 13: Number and Percentage of LMS Peer-to-Peer Message Units Per Student Group Broken Down by Peer Interaction Type

Group ID	Number of Message Units	Basic Interaction	Collaboration	Knowledge Construction
PS-D	120	27%	67%	6%
PS-K	43	42%	58%	0%
PS-M	41	49%	51%	0%
PS-N	30	33%	64%	3%
PS-J	28	36%	60%	4%
PS-Q	28	64%	36%	0%
PS-C	20	15%	85%	0%
PS-H	16	50%	50%	0%
PS-L	12	25%	75%	0%
PS-I	11	64%	36%	0%
PS-E	8	50%	50%	0%
PS-G	7	43%	57%	0%
PS-F	6	67%	33%	0%
PS-O	6	0%	100%	0%
PS-S	6	33%	67%	0%
PS-U	6	83%	17%	0%
PS-P	5	60%	20%	20%
PS-A	4	0%	100%	0%
TOTAL	397	37%	60%	3%

While counting the number of message units is a valid and informative way to examine different types of peer-to-peer message units, another way is by mean word count for each type of peer interaction (see Table 14). Counting the number of words helps describe the length of students' messages in order to express their thoughts for each peer interaction type. An analysis of variance (ANOVA) revealed that there were significantly more words per message unit as the peer interaction progressed in specificity from basic interaction (M=41.54, SD=41.04) to collaboration (M=79.78, SD=84.40) and to knowledge construction (M=134.90, SD=55.92), (F (2,394) = 18.296, $p < .001$). Students therefore took more words to communicate messages to their peers when the content of those messages was coded as collaboration or knowledge construction.

Table 14: Word Count of LMS Peer-to-Peer Message Units Per Student Group Broken Down by Peer Interaction Type

Group ID	Total Sum of Word Counts	Mean Word Counts		
		Basic Interaction	Collaboration	Knowledge Construction
PS-D	10,293	54.72	94.93	121.86
PS-Q	2,643	39.61	58.1	
PS-K	2,423	24.44	79.32	
PS-J	2,054	20.8	97.76	184
PS-M	1,942	41.7	52.76	
PS-L	1,793	34.67	187.67	
PS-N	1,618	37.9	56.32	169
PS-C	916	90	38	
PS-E	867	83.25	133.5	
PS-H	772	35	61.5	
PS-P	493	107.33	28	143
PS-I	483	31.29	66	
PS-O	414		69	
PS-G	374	52.67	54	
PS-F	268	23.5	87	
PS-A	246		61.5	
PS-S	129	10.5	27	
PS-U	110	21	5	
TOTAL	27,838	41.54	79.78	134.90

4.1.1.2 Message Unit Topics

While the previous section describes what types of peer interactions between students took place within the LMS project sites, it does not fully explain what the students were talking about *within* those peer interactions. I therefore analyzed the content of each message unit, each of which could have up to three topics attributed to it (see Table 9). In order to get a sense of what students discussed in each type of interaction, I looked at each message unit topic category and broke down the number of codes in each category by the peer interaction type. In the table below (see Table 15), I have reported the top five topic categories for each peer interaction type.

Table 15: Top Five Peer-to-Peer Message Unit Topic Categories for Each Peer Interaction Type

Peer Interaction Type	Number of Topic Codes (and Number of Message Units)	Topic Category	Percentage of Topic Codes for Peer Interaction Type
Basic Interaction	178 (150 message units)	Face-to-Face Meetings	35%
		General Discussion	20%
		Other Course Projects / Assignments	9%
		Resource Management	5%
		Site Management	5%
Collaboration	429 (237 message units)	Biology Concepts / Procedures	17%
		Writing	13%
		Article Sharing	11%
		Peer Review	7%
		Proposal Details	7%
Knowledge Construction	20 (10 message units)	Biology Concepts / Procedures	50%
		Article Sharing	10%
		Definition of Terms	10%
		Writing	10%
		Confusion	5%

The majority of topic codes assigned to message units coded as basic interaction discussed face-to-face meetings (35%). These message units typically addressed when or where the student group would meet and what was on the agenda for the meeting. For example, one student from group PS-K used the Announcements tool to remind their group members about a face-to-face meeting in the Undergraduate Library (UGLi):

> [PK3]: For those of you who can make it, we're holding a grant proposal meeting today at 9:30pm in the UGLi. We'll meet at the lobby and probably just head down to the basement.

In addition to discussions of face-to-face meetings, many (20%) message units coded as basic interaction dealt with general discussion topics that were usually off-topic interaction that either preceded or interceded with on-topic interactions. For example, a student from group PS-K posted a short Announcement message about their computer problems:

> [PK1]: My computer has been broken since yesterday afternoon; it won't go past a blue screen. I will try to get it fixed today. I'm pissed.

Message units coded as collaboration were assigned a wide variety of topic codes, the most popular of which were biology concepts and procedures (17%). These concepts and procedures were important aspects of the NIH grant proposal assignment for each student group. For example, two students from group PS-C used the Discussion tool to discuss virus quantification and which RNA quantification method was best according to the research literature:

> [PC2]: From what I've read so far it seems that quantifying the amount of the RNA is one of the easiest ways the quantify the amount of virus.
>
> [PC1]: We will probably do RNA quantification. We just need specific, appropriate procedures for doing this in vivo and vitro.
>
> [PC2]: The RNA transcription activity will be quantified by a novel sequence specific method developed by Hosoda et al (2008). The method uses a nicking endonuclease, a dual-labeled DNA probe, and a confirmation-interchangeable oligo-DNA to amplify signal, resulting in accurate detection of the RNA even in the presence of several thousand fold excess cellular RNA.
>
> [PC1]: I read through enough of the paper to get the gist of it. If you've got a handle on it, feel free to write it up, otherwise, I will once I finish with the other sections. As for sequence data, it is available at the NCBI website [link].

Several message units coded as collaboration (13%) were also assigned the topic code of writing. Many of these message units focused on students' comments about various drafts of their collaborative work or guidelines for other students as they worked on different components of the grant proposal assignment. For example, a student from group PS-N posted an Announcement about a new draft of the grant proposal and some of the changes that the student made such as clarifying references and the biological concept of gamma irradiation:

> [PN1]: Just letting you know that I worked a little bit more on the grant and uploaded a FOURTH DRAFT into a new folder in the resources, entitled ENTIRE GRANT PROPOSALS. To make things easier, as you guys make changes go ahead and post new

> drafts of the whole proposal into that folder. // Anyway, I looked over the whole thing and edited a few mistakes out. I also clarified a couple of my references and our gifts, and elaborated on our gamma irradiation a little bit.

The final group of message units were coded as knowledge construction. Half (50%) of these message units were concerned with biology concepts and procedures, similar to the message units coded as collaboration, but where evidence of new learning was also present. For example, a student from group PS-D posted a Discussion message in which they describe their realization that a protein molecule the group was using, B7-1, is actually known as another protein molecule that has unintended effects for the leukemia cells the group is targeting in their proposed study. This realization clarified the understanding of protein molecules for this student group:

> [PD4]: OK, so it turns out that B7-1 is also CD80. This is bad. CD80 is expressed on DCs to stimulate T cells under normal conditions. So CD80 isn't an AML-specific target and would mean that non-leukemic DCs would also get targeted by any adenovirus vector we made with it.

In another example from group PS-D, a student posted an Announcements message in which they clarified the terms that other students were using in their writing for the mock grant proposal assignment:

> [PD1]: Some of the changes includes new defined vocabulary. // First exposure in utero = sensitize // Allergen exposure 7 weeks after birth = challenge // Anywhere in the paper where we talk about either of these exposures I changed them to either sensitized or challenge to make it more clear about which exposure are talking about.

Overall, the majority of peer-to-peer message units were identified as either collaboration (60%) or basic interaction (37%). In terms of the content within the message units, the most popular topic for message units identified as basic interaction was face-to-face meetings. The most popular topic for message identified as collaboration and knowledge construction was biology concepts and/or procedures.

4.1.2 Online Student Surveys

The online surveys were another valuable data source to indicate how students perceived the usefulness of different types of peer interactions. Because project sites can be used to accomplish a wide variety of activities in which different peer interaction types can occur, students were asked to rate the usefulness of various activities in the second survey using a 5-point Likert scale from 1="Not useful at all" to 5="Very useful" (see Table 16). The highest rated activities related to sharing documents (posting documents, 4.86; accessing documents, 4.84) and messages between group members (receiving messages, 4.29; sending messages, 4.20), while the lowest rated activities focused on providing feedback to other group members (answering questions, 3.45; giving comments, 3.20). These ratings could partially explain the distribution of topics coded in students' peer-to-peer message units as the content of the message units could relate to the activities listed in Table 16.

Table 16: Student Ratings of Usefulness of Activities Completed on Their LMS Project Sites

Activity	Survey 2	
	n*	Mean
Posting documents or other materials online	43	4.86
Accessing documents of other materials online that other group members have posted	43	4.84
Receiving messages / announcements / notifications from other group members	13	4.29
Sending messages / announcements / notifications to other group members	11	4.20
Linking to a website outside of the LMS environment	31	3.71
Posting questions to other group members	18	3.61
Collaboratively writing a document with group members online	30	3.50
Receiving comments on my work from other group members	26	3.50
Answering questions from other group members	33	3.45
Commenting on other group members' work	30	3.20

Note: * If students answered "Have Not Used," they were not counted as having answered the survey item.

4.1.3 Student Focus Group Interviews

In the online surveys, students highly rated activities related to storing and accessing documents, websites, and other resources relevant to their mock NIH grant proposal (see Table 16). In the focus group interviews, students discussed how their use of research articles and documents that the students were co-writing helped motivate and shape their groups' peer interactions. For example, a student from group PS-S stated that their group's use of the Resources tool kept both of the group members motivated. Since there were only two students in this group, the Resources tool was a simple way to keep both students involved when one of the group members added or modified a document:

> [PS-S Student]: For the materials section that's when we started using (the project site) … because we wanted to have a comprehensive idea of what exactly we were going to use for that. Whenever we found anything online we would just copy the link and like send it to each other on (the project site) so it was like keeping each other involved in whatever happened.

For group PS-O, posting research papers and sharing materials was a starting point for collaboration between the three student group members. Building on these documents, the students reported that they were able to share their prior knowledge and discovery of new biology concepts with each other:

> [PS-O Student]: And we also shared stories like understanding biology, learning about biology, like posting the papers that we found that were helpful to us so that other people could help us. … We definitely were able to collaborate on what we knew about our project in that sense.

Overall, students' comments in the focus group interviews indicate that while some students were initially concerned with using the LMS project sites for file management, they also used the interactive tools to discuss and collaborate about articles, websites, and documents that the students were co-writing. These interviews bolster the data from other sources that show that students were engaged in a variety of different types of peer interactions within the LMS, but much of that interaction was focused around or began with the documents added and accessed within the Resources tool.

4.1.4 Instructor Interviews

Examining how the instructor uses the LMS on his course site might partially explain the students' types of peer interactions on their project sites. The instructor stated in the start-of-term interview that he used the LMS in order to easily communicate with students. In particular, he mentioned the Announcements and Resources tools as easy mechanisms to notify students when there were new course materials or changes:

> [Instructor]: I use Announcements a lot because it's easy for me to tell students when there's new resources available; when something changed with respect to course that kind of thing. … Since it's secure and it's only accessible to students that are registered it's a pretty good way to communicate all that stuff with students.

During the end-of-term interview, the instructor expanded on his use of LMS communication tools, stating that with a large course, the LMS is an effective way to disseminate important course information:

> [Instructor]: …With this kind of a course, students come and go pretty often and being a lab course it's only once per week that the students are all assembled in one area and as an upper level lab course a lot of students don't come to lecture so I rely heavily on the announcements portion of (the LMS) to disseminate information.

The instructors' use of the LMS to share information and important documents related to the course is similar to some of students' use of the LMS for their mock grant proposal assignment, such as sharing research articles or information pertinent to the details of their proposed research.

4.1.5 Summary

This research sub-question investigated the types of peer interactions between students that took place within the LMS. Nearly all of the peer-to-peer message units were identified as either collaboration (60%) or basic interaction (37%). Students found sharing documents and messages the most useful interactive activities within LMS, while the lowest-rated activities were related to providing feedback to other group members. Additionally, students indicated that the Resources tool might have been a way to keep group members motivated as well as a first step towards greater group interaction and knowledge sharing. The instructor revealed that he also used the LMS to easily share information and important documents related to the course. Overall, students engaged in a wide variety of peer interactions via their LMS project sites, many of those peer interactions were collaborative, and some of the peer interactions, although proportionally very few, were focused on the construction of new knowledge between students.

4.2 Research Sub-Question B: Which Tools Do Students Elect to Use to Interact Within LMS and Why?

Learning management systems are designed to provide the users with an integrated suite of tools that can facilitate a variety of communication, management, and peer interaction activities (Malikowski et al., 2007). Because these activities can occur in multiple tools, each with specific features and affordances, it is important to know which tools students used to in order to better understand how the design of those tools may have influenced students' peer interactions. Furthermore, students were able to choose which tools to activate in their LMS project sites as well as when and how to use those tools. Thus, it is important to not only investigate *which* tools students used in order to complete their mock NIH grant proposal assignments, but also *why* they chose to use them.

In order to answer this research sub-question, I used all five of the data sources:

- Students used four different tools to create the peer-to-peer message units. How the students used these four tools gives some insight as to why students elected to use these interactive tools.

- The event logs provide a comprehensive quantitative overview of which tools students used in their LMS project sites and how much they used those tools for different types of activities (e.g., adding versus revising) in comparison with other tools.
- Students were asked about their perceptions of the LMS tools' usefulness for collaboration in the online surveys, which helps explain the findings from the other data sources.
- Students' opinions about and reasons for using the different LMS tools were further explored in the focus group interviews.
- In his interviews, the instructor described which LMS tools he used for his course site, which could help explain students' choices for tool activation.

4.2.1 LMS Peer-to-Peer Message Units

Students used four different tools to interact via the LMS, as captured in the peer-to-peer message units (n=397). Most of these messages between students occurred within the Announcements tool (54%) followed by the Chat (26%) and Email Archive (11%) tools. When analyzing these tools by peer interaction type (see Table 17), the majority of message units for each tool are collaborative, except for the Email Archive tool (within the LMS) in which the majority (61%) of messages are basic interaction, possibly reflecting the types of messages that were sent between students using their personal email accounts (external to the LMS).

Table 17: Peer-to-Peer Message Unit Totals and Percentages by Tool and Peer Interaction Type

Tool	Number of Message Units	Basic Interaction	Collaboration	Knowledge Construction
Announcements	216 (54%)	39%	60%	1%
Chat	101 (26%)	35%	59%	6%
Email Archive	44 (11%)	61%	39%	0%
Discussion	36 (9%)	17%	80%	3%

Within the Announcements and Email Archive tools, students often posted individual messages that did not directly respond or refer to other students' messages. In the Discussion tool, perhaps due to the threaded structure of the user interface, students often responded directly to each others' messages, as seen in this example from group PS-

C in which two students discussed materials that should be "purchased" for their mock grant proposal:

> [PC2]: Do you think we should buy both the 5 prime and 3 prime (C and N) his tag addition kits, just in case?
>
> [PC1]: Since the experiment relies on functional protein, it would probably be a good idea.

However, there were a few instances where students did directly respond to each other in the other asynchronous tools. For example, one student from group PS-D posed questions to the group via the Announcements tool about different biological procedures relevant to their NIH grant proposal. After another student used the Announcements tool to answer the questions with relevant estimated figures, the first student replied again with the opinion that the overall proposed budget was too high:

> [PD1]: So I found a site that gives us the pricing for the germ free facilities (this means you don't have to pester your PI about prices [PD4]). It's really not as bad as I thought it would be and based on that, I believe we will have more than enough money to fund our grant (based on an initial analysis of the pricing). All PD6 and I need now are numbers from [PD3] and [PD5] reflecting number of ELISA assays and a rough estimate of the number of mice we will use. Also we need to know whether or not we will be doing any other types of assays that we talked about including immunostaining. If we decide that we are only going to do ELISAs and Flow I am concerned that [the Instructor] will have a problem with that considering it has to be, at minimum, a 1 year project and that we could be criticized that our data isn't sufficient enough to make any claims without more evidence. I could be wrong on that though. Anyway I saw what you guys have posted so far and it looks great! Keep up the good work!
>
> [PD3]: In response to some of [PD1]'s questions: // We are estimating to have 8 groups of 16 mice = 128 total mice. (I changed it to work out so that 4 of the same group were in a cage) // Timing of how long and with how many mice is coming soon with [PD5]'s section..... // ELISAs: bc we have 9 compounds we want to test and 128 mice.....with 2 exposures of which we are testing.....we will be doing (woah...) 2,304 tests....that seems like a lot...we may have to change that. // FLOW: we need 5 anti-bodies * 128 mice * 2 =

1,280 anit-bodies (for the flow....plus the flow cytometer) // I think that's about all for now...see you all tomorrow at 11 am in the Dana Commons.

[PD1]: Hey guys, In response to [PD3]'s announcement on budget, we will have to find a more cost-effective way to run the protein assays. At about $500 a kit and 2304 trials that is -- yes, well over a million! ($1,152,000 to be exact). We need to discuss this on Sat.

The peer-to-peer message units demonstrate that students used four interactive tools in different ways, sometimes posting single messages to the group as a whole and other times posting message threads in which there was back-and-forth interaction between two or more students. In terms of overall count of message units, students used the Announcements tool the most and the Discussion tool the least.

4.2.2 LMS Event Logs

The LMS event log provides quantitative data representing how much students used the various LMS tools during the semester for their course assignment. Table 18 below breaks down the number and kinds of events per site (14,298 total events). Resources (50%) dominated the event log in terms of amount of use and was also used by all 21 student groups. In order to better understand how students used the LMS tools, I first broke down the overall events for each tool into three different types of use. Within each LMS tool, users can add new items, delete items, and revise items. The majority of events were add-related, with the exception of the Wiki tool.

Since the add-related events dominated the percentage of user actions for most tools, I next investigated these kinds of events in each LMS project site. The median number of add-related events were 78 Resource additions, 4 Announcement messages, 1 Chat message, 0 Discussion posts, 0 archived emails, and 0 Wiki pages. The interactive tools' (Announcements, Chat, Discussion, Email Archive, Wiki) medians are low compared to Resources because only a few groups used these tools (see Table 18).

Table 18: Total Number of Events and Breakdown of Event Types for Each LMS Tool

Tool	Number of Events **	Number of Groups Using Tool	Add Events	Delete Events	Revise Events
Resources *	7,099 (50%)	21	24%	5%	6%
Chat	746 (5%)	12	99%	1%	
Announcements	214 (2%)	15	93%	1%	6%
Site Maintenance	130 (1%)	21			100%
Email Archive	47 (0.3%)	6	96%		4%
Discussion	45 (0.3%)	6	96%	2%	2%
Schedule	21 (0.1%)	5	48%		52%
Wiki	13 (0.1%)	2	15%		85%

Note: * 65% of the Resources activity were access-related events (e.g., downloads)
** 42% of all logged activity was related to students' site logins and logouts

The data from the event logs also shows that the Resources tool might have acted as a type of "gateway" for greater activity in other LMS tools. For example, groups PS-D, PS-M, and PS-P all had substantial Resource tool activity (1,028, 919, and 619 total Resource events, respectively). Those same groups also actively used at least one interactive tool (e.g., Chat). The groups that had very little Resource tool activity, PS-R and PS-T (18 and 54 events, respectively) had no activity in any of the interactive tools.

Overall, Resources was by far the most used LMS tool, representing 50% of all logged activity within the LMS. The Chat (5%) and the Announcements (2%) tools were the most used interactive tools and the Schedule and Wiki tools (0.1% each) were used the least of all LMS tools.

4.2.3 Online Student Surveys

Students were asked to rate the usefulness of the LMS tools for collaboration on a 5-point Likert scale from 1="Not useful at all" to 5="Very useful" in both online surveys. The results for Survey 1 (beginning of term) and Survey 2 (end of term) are reported below (see Table 19). There were significant differences, over time, for the students' opinions of Resources (t (30) = 3.321, p = .002), Email Archive (t (14) = 2.747, p = .016), and Schedule tools (t (15) = 2.671, p = .017). The highest rated tools were Resources (4.98) and Announcements (4.26) and the lowest rated tools were Schedule (2.68) and Wiki (2.40). This is consistent with log data showing that the Resources tool was used the most and the Schedule and Wiki tools were used the least. For the Resources and

Announcements tools, the mean ratings increased between surveys 1 and 2 while the mean ratings for all other tools decreased.

Table 19: Student Ratings of Usefulness of LMS Tools on Their Project Site for Collaboration

Tool	Survey 1		Survey 2		Mean Difference
	n	Mean	n	Mean	
Resources	50	4.62	42	4.98	+ .36**
Announcements	51	4.20	39	4.26	+ .06
Email Archive	52	3.83	22	3.27	- .56**
Chat	50	3.38	29	3.21	- .17
Web Content (URL Links)	47	3.62	20	3.20	- .42
Discussion	51	3.29	22	3.09	- .20
Schedule	49	3.78	19	2.68	- 1.10**
Wiki	43	3.14	15	2.40	- .74

Note: ** $p < .05$

In addition to asking students to rate the usefulness of each LMS tool for collaboration, students were also asked to explain which tools they thought were the *most* useful for collaboration. Coding of these answers from survey two (40 total comments) suggested the basis for the tool ratings. The highest rated tool, Resources (4.98), was identified by 39 students. Most of the comments reflected students' opinion that Resources was useful for sharing research articles, writing drafts, and other information to other group members:

> [PC1]: The resources tool … allowed the group to pool useful articles found by individual members, and allowed work completed to be accessed by all members for review.
>
> [PI1]: Resources, definitely. The ability to have a virtual filing cabinet was wonderful, and we could instantaneously pass finished documents or newly found sources of information to the entire group, and, it would be securely archived.

The second highest rated tool, Announcements (4.26), was also mentioned by 6 students as useful for collaboration. Students stated that Announcements allowed them to contact all group members quickly and also keep track of other group members' activities related to the course project:

> [PD4]: Announcements allowed us to keep track of who had done what at what time and to assess overall group progress.

> [PL4]: Announcements were useful because it made it easy to reach all group members quickly without having to deal with emails.

When examining what LMS tools students used and why, it is also important to examine what tools they used outside of the system because that external use may have affected how students used the LMS tools. In the second survey, students were asked to identify any non-LMS technologies they used to collaborate with their group members (see Table 20). The most popular technologies that students reported using were email (86%) and telephone or cellular phone (84%).

Table 20: Percent of Students Reporting Their Use of Non-LMS Collaborative Technologies

Technology	Percent of Students Reporting Use (n=43)
Email	86%
Telephone / Cell Phone	84%
Instant messaging (e.g., AIM)	23%
SMS text messaging (e.g., texting)	23%
Google documents	5%
Peer connection websites (e.g., Facebook)	2%

Similar to the qualitative question about LMS tools above, students were asked to explain their use of the non-LMS collaborative technologies (35 total comments). Twenty-nine students commented on their use of email and/or telephone. Students thought that email was useful because of its common use and afforded the ability for detailed messages, while telephone was useful for instantaneous and immediate conversation with group members:

> [PR1]: E-mail is easy to use because we all check it everyday. Phone is easy because it's instantaneous conversation and facilitates discussion better. … The combination of these (technologies) and the (project) site allowed us to not have to meet in person yet still work together.

> [PD4]: Emails were good for questions directed to specific group members instead of the whole group. Could be more detailed than a phone call and made an archived record of communications. … Email helped us to communicate when we broke the group up into sub-groups to work on specific aspects.

Overall, the data from the online student surveys indicate that students valued the Resources and Announcements tools the most for collaboration. While over 80% of students indicated that they also used non-LMS technologies such as email and phones, students claimed that the LMS tools were very valuable for their groups' collaboration and successful completion of their NIH grant proposal projects.

4.2.4 Student Focus Group Interviews

The focus group interviews were an important way to help understand why students used the different tools within their LMS project sites. In general, students discussed the tools they used the most as well as the difficulties they experienced with these tools.

As seen in the online survey results and event logs above, Resources was the most heavily used and highly rated tool by students. In their focus group interviews, students explained why this tool was so helpful for their grant proposal assignments. Students mentioned various affordances of the tool as well as comparing the ease of the Resources tool to standard email messages:

> [PS-P Student]: It was nice having everything we were looking at in one spot, you could log into one spot and everyone could access it; everyone can upload; that was a nice feature.

> [PS-O Student]: It's a lot better than just sending it out just by email to someone because it stays in the same place on the site and you don't have to filter through your email box and try to find it again if you wanted to look at it down the road. It was nice to know it was there and have immediate access to it.

Students also commented on their use of another popular tool, Announcements, and why they thought that this tool was valuable:

> [PS-D Student]: …if we had talked about something in a meeting, or I go back and I'm writing part of a paper and I feel like I have to change what we discussed I'll say well guys I don't think that was right. I'm going to do this now so that they don't just see it on there and think I thought we weren't going to do this.
>
> [PS-M Student]: Usually we send announcements about what each of us has to do for the next meeting. Like at the end of one meeting like one of us will write an announcement saying like this is what you have to do. Or like we set up meeting times.

The groups that used the more interactive tools like Chat also commented on their use of those tools. Group PS-D used the Chat tool more than any other group and found that it was particularly useful if all six students were not able to meet face-to-face at the same time:

> [PS-D Student]: Well if people were in different places and couldn't get to a central meeting area it was good so that we could still have our weekly meetings and get stuff done.

However, students from both group PS-D and PS-M found that they had problems with the Chat tool, and the technology did not always meet their expectations or needs to communicate with other group members:

> [PS-D Student]: …it got to the point where I didn't think that it was adequate to meeting in the chat room because it seemed like we needed to have a more complex discussion and it just seemed like the back and forth on the chat room wasn't going to cut it so we needed to meet as a group so we could have interactive…the chat room was more let's get these points across. PD3 you do this, PD4 you do that, that sort of thing.
>
> [PS-M Student]: People usually don't go on it. She might send out a chat saying hello at 3:56 and then like 4:20 I go in there and it's too late. So I think it's hard that (it is) not our first instinct to look to see if somebody's in the chat room.

Overall, the focus group interviews demonstrated that students used the LMS tools because it allowed them to store and access files and documents important to their course project and also communicate about their grant proposal assignment.

4.2.5 Instructor Interviews

The instructor explained in the start-of-term interview that he was very selective about which LMS tools he activated on his course site and how he used them:

> [Instructor]: Most often I don't use all the tools. I use very selective ones. Resources so that I can give them a lot of materials. … I use Announcements a lot because it's easy for me to tell students when there's new resources available; when something changed with respect to course that kind of thing. … other than that I don't use any other (tools). I don't find a need for them. It's not that I think they're bad I just don't find a need for them in the courses I teach.

While it is difficult to infer that because the instructor predominately used Resources and Announcements in his LMS course site, students likewise used those tools the most in their LMS project sites, it is important to note that these are the most commonly used tools across all LMS course sites (Lonn & Teasley, 2008), and thus students have the most exposure with these tools in a typical course.

4.2.6 Summary

This research sub-question investigated which tools students used to interact within their LMS project sites and why. The most used tool for the peer-to-peer message units was Announcements tool, and the most used tool overall was the Resources tool. Students also rated the Resources and Announcements tools the most useful for collaboration in the online surveys, and their ratings of these tools increased throughout the semester, while ratings of all other LMS tools decreased. Overall, students claimed that the LMS tools, the Resources and Announcements tools in particular, were easy to use and allowed them to store important documents and discuss them all in one convenient online space.

4.3 Research Sub-Question C: Within the LMS, How Often do Students' Peer Interactions Occur Over Time?

Students in the biology course were introduced to the mock NIH grant proposal assignment when the course began in January, and they were expected to continually work on this assignment until the final due date in early April. While the previous research sub-question identified which tools students used in their LMS project sites and how much they used them, it is not known how often students used these tools throughout the semester. This section will therefore investigate how students used their LMS project sites over time.

In order to answer this research sub-question, I utilized three data sources:

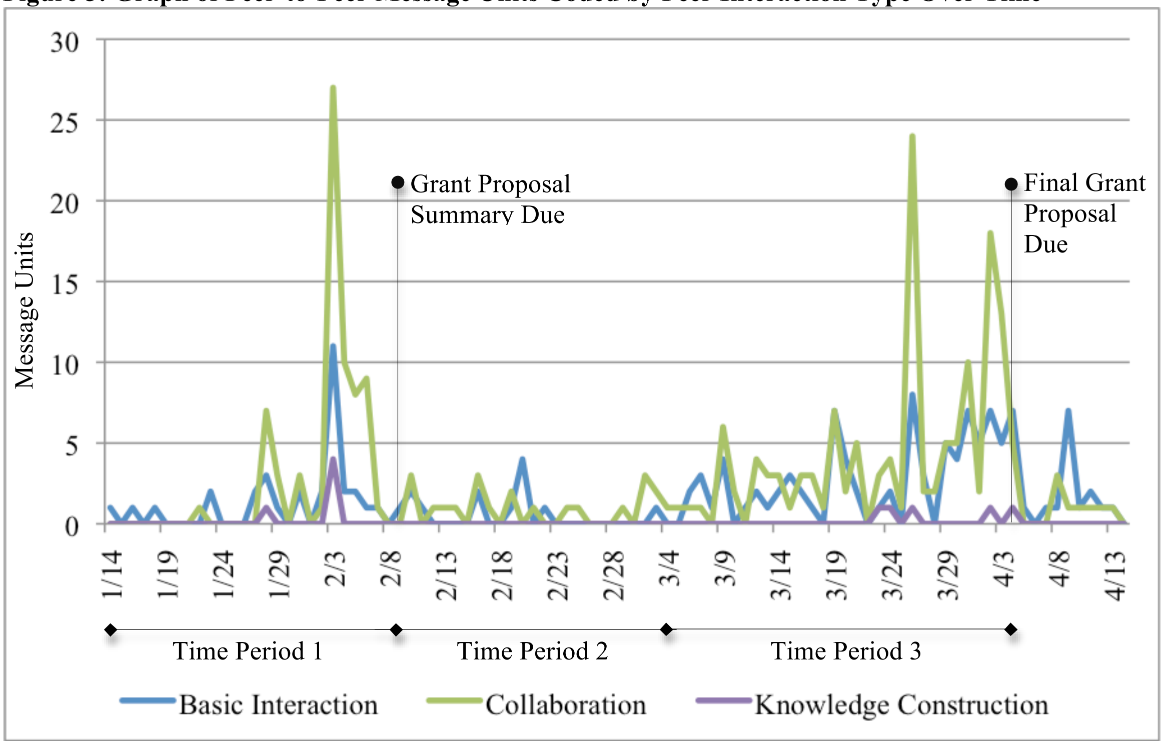
- The peer-to-peer message units helped describe the different types of peer interactions and topics discussed within the LMS throughout the semester.
- The log events were instrumental in identifying differences in tool use over time, differences between groups' overall use of the LMS throughout the semester, and identifying the kinds of files that students discussed at different times during the course of their group projects.
- In the online surveys, students were asked about their frequency of use of the LMS project sites, which added the students' perception of their use to this research sub-question.

4.3.1 LMS Peer-to-Peer Message Units

4.3.1.1 Differences in Peer Interaction Types Over Time

In earlier analyses (see Table 12), I coded the 397 peer-to-peer message units into three interaction categories: basic interaction (37%), collaboration (60%), and knowledge construction (3%). When examining these interaction types over time, the collaboration category, more than any other category, had two strong spikes of activity in early February and early April (see Figure 5). These spikes relate to the two main deadlines for the NIH grant proposal assignment: 1) A proposal summary with group members and project topic on February 7th, and 2) The final grant proposal document on April 4th (See Figure 3 for a timeline of all course milestones and data collection activities.) Collaboration between students peaked just before both of these deadlines. There were also increased amounts of basic interaction between students leading up to the final document deadline.

Figure 5: Graph of Peer-to-Peer Message Units Coded by Peer Interaction Type Over Time



In order to better examine this pattern over time, I organized the message units into three time periods: 1) before the grant proposal summary deadline (January 1st through February 7th), 2) the mid-term period (February 8th through March 4th), and 3) the month before the final grant proposal deadline (March 5th through April 4th) (see Table 21). These time periods were selected based on patterns in students' actions and their relationship to course milestones (see Figure 3). Note that 24 message units occurred after the final grant proposal deadline and are therefore not included in this analysis. In general, these messages were about students' grades, expressions of glee in turning in the group project, and assorted off-topic interactions. Following the pattern observed above (see Figure 5), the majority (62%) of message units occurred in the month before the final grant proposal deadline, and many (29%) occurred in the time period leading up to the grant proposal summary deadline, but only a few (9%) message units in the time period in-between these two milestones. This pattern was consistent across all three peer interaction types.

Table 21: Total Number of Message Units and Percentages By Peer Interaction Type for Each Course Time Period

Peer Interaction Type	Number of Message Units	Time Period 1	Time Period 2	Time Period 3
Basic Interaction	150	24%	10%	66%
Collaboration	237	30%	10%	60%
Knowledge Construction	10	50%	0%	50%
Total	397	29%	9%	62%

4.3.1.2 Differences in Message Unit Topics Over Time

The peer-to-peer message units were coded topically into 27 different categories to arrive at a total of 627 codes (see Table 9). In order to analyze students' peer interactions over time, I analyzed the top five categories for each interaction type (identified in Table 15) and divided the message units for each topic category into the three time periods described above (see Table 22). Students were most actively interacting about all of these topics around the two course milestones, particularly the final grant proposal deadline.

Table 22: Top Five Peer-to-Peer Message Unit Topic Categories for Each Peer Interaction Type in Each Course Time Period

Peer Interaction Type	Topic Category	Number of Topic Codes	Time Period 1	Time Period 2	Time Period 3
Basic Interaction	Face-to-Face Meetings	59	14%	12%	75%
	General Discussion	31	42%	6%	52%
	Other Course Projects / Assignments	10	50%	10%	40%
	Resource Management	8	0%	0%	100%
	Site Management	9	67%	22%	11%
Collaboration	Biology Concepts / Procedures	72	32%	11%	57%
	Writing	51	8%	6%	86%
	Article Sharing	43	51%	2%	47%
	Peer Review	31	26%	3%	71%
	Proposal Details	30	30%	7%	63%
Knowledge Construction	Biology Concepts / Procedures	10	50%	0%	50%
	Article Sharing	2	100%	0%	0%
	Definition of Terms	2	0%	0%	100%
	Writing	2	0%	0%	100%
	Confusion	1	0%	0%	100%

4.3.1.3 Student Comments Related to Course Milestones

There were a few instances leading up to the final grant proposal deadline where students directly mentioned due dates or seemed to feel pressure to finish their assignments. For example, a student from group PS-D posted an Announcement in mid-March about more regular face-to-face meetings:

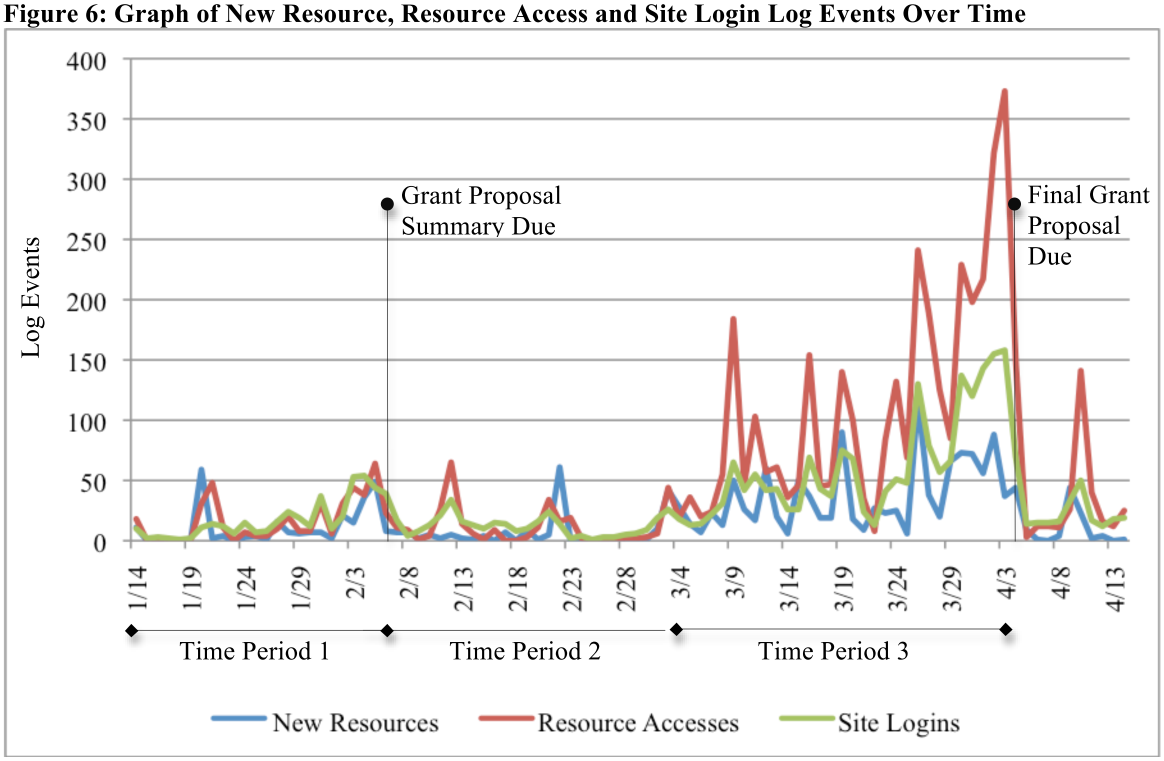
> [PD3]: I was going through the syllabus and realized that we only have 3 weeks from today till our grant proposal is due. I think that it would be wise that we meet tomorrow after [PD4], [PD6], and I (and whom ever else can come) meet with (the instructor). In addition to that we need to meet again on Sunday. We really need to get going on this project.

Overall, the distribution of peer-to-peer message units and topics over time demonstrates that peer interaction was particularly high close to the grant proposal summary deadline on February 7th and even higher as the final grant proposal deadline on April 4th approached.

4.3.2 LMS Event Log Data

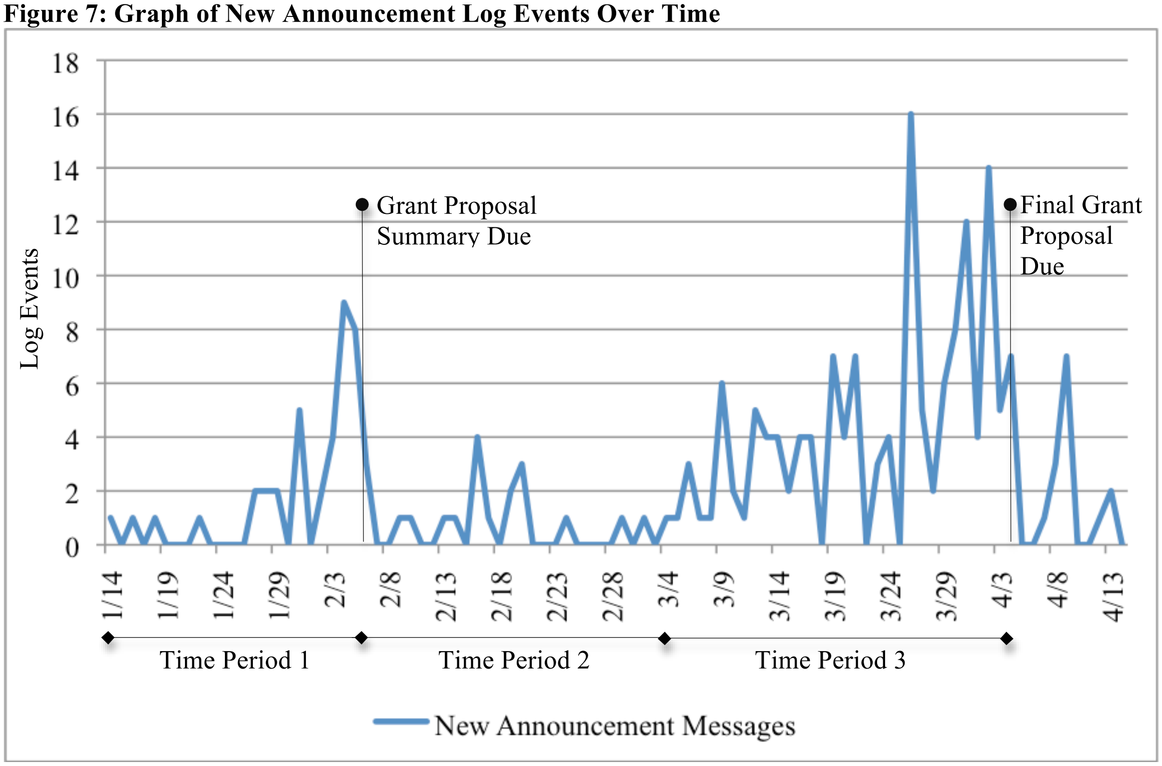
In order to get an initial look at how students' use of their LMS sites changed throughout the semester, I first graphed the most prevalent events in the log data (14,298 total events): new Resource items (12%), accesses of Resource items (33%), and project site logins (21%) (see Figure 6). The pattern of these events is a little different from the peer-to-peer message units (see Figure 5). While there was some activity around the grant proposal summary deadline on February 7th, there was a far greater amount of activity close to the final grant proposal deadline on April 4th. The date with the most new Resource items was March 26th (115 events). For accesses of Resource items (373 events) and project site logins (158 events), the date with most activity was April 4th, the day before the final grant proposal was due.

Figure 6: Graph of New Resource, Resource Access and Site Login Log Events Over Time



I was also interested in the use of the interactive tools over time. Since Announcements comprised 54% of the peer-to-peer message units (see Table 17), I graphed new Announcement messages over time (see Figure 7). As with the Resources and Site Login events, most of the activity was evident around the two course milestones, with the majority of activity occurring just before the final grant proposal deadline. The date with the most new Announcements was March 26th (16 events).

Figure 7: Graph of New Announcement Log Events Over Time



Given the pattern of use shown in the above figures of log events, I sought another way to describe these data in order to evaluate not only the raw number of log events, but how those events were clustered within a particular session for each user. One session is defined as the total amount of activity for each user for as long as they are logged in. In the LMS used in this study, if a user logs out and then logs back in or if more than 30 minutes expire after the user has last clicked anywhere within the LMS, a new session is recorded in the database. For example, if a user first logs into their project site to post a Discussion message, then goes to one of their course sites to submit an assignment, but later returns to the project site to see if anyone has responded, all of that activity is recorded as one user session in the event log database. I was interested in the total number of sessions as well as the breakdown of sessions for the three time periods used in above analyses (see Tables 21 & 22). This analysis revealed that the average number of sessions was fairly consistent for the first two time periods in the semester and then dramatically increased in the month preceding the final grant proposal deadline. With the exception of groups PS-B and PS-D, the total number of sessions decreased after the grant proposal summary deadline, and then dramatically increased in the month preceding the final grant proposal deadline, often doubling or tripling the number of sessions in the first time period. There was not a significant difference between the first and second time period's average number of sessions, but there was a significant between the first and third time period's average number of sessions (t (20) = 8.098, $p < .001$) and the second and third time period (t (20) = 7.961, $p < .001$).

As shown in the coding of topic categories within the content of the LMS peer-to-peer message units, students used the LMS project sites to collaborate about article sharing, writing, and peer review. The LMS event log data can help explain what files or websites students were collaborating around in order to gain better perspective of the types of collaborative interactions taking place within LMS. I therefore queried the log files for the name of the most accessed Resources file for each student group in February, March and April and then summarized the content of those files. In February, 50% (n=14) of the files were research articles about various biological concepts, presumably related to the topics of students' grant proposals. In March, 61% (n=18) of the files were summaries or drafts of the grant proposal that students were writing and posting for peer review and comment. In April that percentage increased (70%, n=20) for the same type of file. These data demonstrate that students were using the Resources tool for different purposes throughout the semester as the project evolved, first for research articles and later for writing drafts and summaries. These different purposes correspond to the topics discussed via the LMS interactive tools in the peer-to-peer message units.

The above analyses for the log event data indicate that, like the peer-to-peer message units, overall use was moderate preceding the grant proposal summary deadline. Students' LMS use then somewhat decreased in terms of log events (but not overall sessions) for the second time period, and finally, the students' use dramatically increased in the month preceding the final grant proposal deadline.

4.3.4 Online Student Surveys.

In the online surveys, students were asked how often they visited their project sites, which offers self-reported perceptions to compare with the raw login data from the event logs (see Table 23). At the beginning of the term, 55% of project site users thought that they would use their site at least a few times a week or more and by the end of the term, 74% of project site users reported using their site at that frequency. The most frequent response across both surveys was using the project site a few times a week (42-51%) and the least frequent response was using the project site only a few times during the semester (5-7%). This finding supports the pattern of overall LMS use seen above, where there is a moderate level of use early in the term and a higher level of online activity near the final grant proposal deadline. Despite this pattern, there was not a significant difference between survey 1 and 2 for how students answered this survey question (X^2 (4, N=83) = 4.183, p = .382).

Table 23: How Often Students Reported Using Their Project Sites

Survey	Few times during the semester	Few times a month	Once a week	Few times a week	Daily (once or more)
Survey 1 (n=40)	7%	13%	25%	42%	13%
Survey 2 (n=43)	5%	9%	12%	51%	23%

4.3.5 Summary

All three data sources used to answer this research sub-question revealed a similar pattern of use of the LMS over time. First, the peer-to-peer message units revealed two large frequency spikes of collaboration near each of the two course milestones. Additionally, basic student interaction, overall, increased in the final month preceding the final grant proposal deadline. The event logs also showed a similar pattern of use overall for the interactive tools (e.g., Announcements, Chat, Discussion, and Email Archive) and students' responses to the online surveys also show that students reported that their use of the LMS increased throughout the semester. Overall, the data sources demonstrate that students tended to procrastinate and wait until the time periods prior to the course milestones to conduct the bulk of their work, as evidenced by their online LMS activity.

4.4 Research Sub-Question D: What Factors Influence Whether Students' Basic Interactions Within LMS can be Characterized as Collaborative?

In this dissertation study, any kind of communication that took place online within a LMS tool was considered as evidence of basic interaction between students. Collaboration, a subset of basic interaction, was communication between students within a LMS tool that served to develop and/or sustain shared ideas about a collective problem (e.g., the mock NIH grant proposal). I am interested if there were any potential factors that may have influenced whether the interactions between students were also able to be distinguished as collaboration. For example, how well the students within each group worked together on their mock NIH grant proposal project could have impacted their ability to effectively communicate with each other and could therefore be one possible factor whether the students were able to use the LMS to collaborate.

In order to answer this research sub-question, I utilized all five data sources:

- The peer-to-peer message units were used to explore differences between different group sizes and the related types of peer interactions.
- For the LMS event logs, I looked at interactive events against content sharing events to see which groups were more likely to have collaborative interactions. I also investigated the distribution of interactive events within each student group.
- A variety of different items were explored from the online surveys to help answer this research sub-question including information about students' face-to-face meetings, the perceived benefits of using LMS project sites, how well the student groups worked together, and the LMS' perceived impact on the success of the course project.
- Students' responses during the focus group interviews added depth and important information about various factors discovered in other data sources.
- The instructor interviews helped explain the overall context and requirements regarding the mock NIH grant proposal assignment, which may have affected whether students' interactions wee able to become collaborative.

4.4.1 LMS Peer-to-Peer Message Units

In the start-of-term interview, the Instructor mentioned that, in the past, some larger groups of five or six students have had difficulty working together on the mock NIH grant proposal project. I therefore wanted to see if the size of the student group affected the types of peer interactions in this dissertation study. I examined the mean and median number of message units for each peer interaction type (see Table 24). While there appeared to a large difference in the mean and median number of units for groups with six students when compared to the other group sizes, it should be noted that two of the six-student groups had a combined 3 basic interaction message units and 5 collaboration message units while one group had 32 basic interaction and 81 collaboration message units. There were similar disparities in the student groups with three and four students. Overall, an analysis of variance (ANOVA) revealed that there were no significant differences between the different sizes of student groups based on the mean number of message units coded as basic interaction (F (4,13) = 1.034, p = .427), collaboration (F (4,13) = .946, p = .468), or knowledge construction (F (4,13) = .667, p = .626). Group size was therefore not an influential factor regarding whether students' basic interactions within LMS could be characterized as collaborative.

Table 24: Mean (And Median) Number of Peer-to-Peer Message Units By Group Size

Number of Students Per Group	Number of Groups*	Total Number of Message Units	Mean (and Median) Number of Message Units		
			Basic Interaction	Collaboration	Knowledge Construction
2 Students	2	12	3 (3)	3 (3)	0 (0)
3 Students	6	102	6.8 (5)	10 (8)	0.2 (0)
4 Students	2	36	7 (7)	10.5 (10.5)	0.5 (0.5)
5 Students	3	34	5.3 (5)	6 (8)	0 (0)
6 Students	5	213	14.6 (18)	26.4 (21)	1.6 (0)

Note: * Only the 18 groups with at least one peer-to-peer message unit was included in this analysis

4.4.2 LMS Event Log Data

4.4.2.1 Comparing the Use of Content Sharing and Interactive Tools

Since students could choose which LMS tools to activate and use, if students chose not to use interactive tools (e.g., Announcements, Chat, Discussion, Email Archive, Wiki), then they were far less likely to have any kind of collaboration via their LMS project site. I therefore analyzed all of the activity on each project site (after removing site login/logout and site maintenance events) and determined how much of the total activity came from content sharing tools (Resources and Schedule) versus interactive tools and corresponding numbers of peer-to-peer message units coded as collaboration (see Table 25). The median percentage for content sharing events was 94% of total activity with only 6% median percentage of interactive events.

Table 25: Percentage of Content Sharing and Interactive Events Per Student Group and Corresponding Number of Peer-to-Peer Message Units Coded as Collaboration

Student Group ID	Log Events			Peer-to-Peer Message Units	
	All Events*	% Content Sharing	% Interactive	Total # of Message Units	# of Collaboration Message Units
PS-S	72	56%	44%	6	4
PS-D	1626	64%	36%	120	81
PS-K	362	86%	14%	43	25
PS-H	129	87%	13%	16	8
PS-N	265	87%	13%	30	19
PS-Q	237	86%	12%	28	10
PS-M	1022	90%	10%	41	21
PS-P	683	91%	9%	5	1
PS-F	300	93%	7%	6	2
PS-I	493	94%	6%	11	4
PS-J	532	94%	6%	28	17
PS-C	427	95%	5%	20	17
PS-E	246	96%	4%	8	4
PS-G	277	97%	3%	7	4
PS-U	201	97%	3%	6	1
PS-L	578	98%	2%	12	9
PS-A	219	99%	1%	4	4
PS-O	348	99%	1%	6	6
PS-B	98	100%	0%	N/A	N/A
PS-R	18	100%	0%	N/A	N/A
PS-T	54	100%	0%	N/A	N/A
Median	277	94%	6%	11.5	7

Note: * All events equals total site events minus site login/logout and maintenance events.

Based on this analysis, I wanted to know if the number of interactive events was related to the number of peer-to-peer message units coded as collaboration (i.e., if there was a higher number of interactive events, would the number of collaborative message units also be higher?). However, a correlational analysis revealed that there was no correlation (r (17) = -.122, p = .630) between the number of interactive events (M=57.06, SD=135.82) and the number of peer-to-peer message units coded as collaboration (M=13.17, SD=18.49). A subsequent analysis revealed that there was a significant correlation (r (17) = .527, p = .025) between the percentage of interactive events (M=10.56, SD=11.62) and the number of peer-to-peer message units coded as collaboration (M=13.17, SD=18.49), although there was no such correlation (r (16) =

.079, p = .764) between the percentage of interactive events (M=9.06, SD=10.03) and the number of peer-to-peer message units coded as collaboration (M=9.18, SD=7.67) once the results from group PS-D, an outlier in this analysis, were removed. The distribution of content sharing versus interactive log events was therefore not an influential factor regarding whether students' basic interactions within LMS could be characterized as collaborative.

4.4.2.2 Distribution of Interactive Site Activity Among Site Members

Similar to the analysis above that looked at the connection between overall number of interactive events logged by the LMS and the relationship to the number of peer-to-peer messages coded as collaboration, I was also interested in the breakdown of those interactive log events among the group members within each group. If activity on the LMS project site was unequal across group members, it is possible that the presence of an overly dominant group member, in terms of LMS interactive usage, could have prevented students in the group from collaborating via the technology. In order to examine the distribution of interactive site activity for each LMS project site, I summed the total number of log events for each student for the Announcements, Chat, Discussion, Email Archive, and Wiki tools and divided them by the total number of log events for those same tools on each site. In this analysis, the most and least active students' percentage of total interactive activity within the LMS for each group was compared with the groups' peer-to-peer messages coded as collaboration (see Table 26). For the groups with five or six students, the most evenly distributed group was PS-H, where four students each accounted for 23% of the interactive tool activity, and the least evenly distributed group was PS-P where one student accounted for 56% of the activity. For small groups with two or three students, the most evenly distributed group was PS-S, where one student accounted for 59% of the interactive tool activity, and the least evenly distributed group was PS-G, where one student accounted for 86% of the activity.

Table 26: Most and Least Active Student in Terms of Percentage of Interactive Events Per Student Group and Corresponding Number of Peer-to-Peer Message Units Coded as Collaboration

Student Group ID	Log Events				Peer-to-Peer Message Units	
	Number of Students	All Interactive Tool Events	% Events: Most Active Student*	% Events: Least Active Student*	Total # of Message Units	# of Collaboration Message Units
PS-D	6	592	30%	7%	120	81
PS-M	6	98	53%	2%	41	21
PS-P	6	64	56%	0% (2)	5	1
PS-K	6	49	39%	4%	43	25
PS-N	3	35	49%	11%	30	19
PS-J	4	34	35% (2)	12%	28	17
PS-S	2	32	59%	41%	6	4
PS-Q	3	30	50%	20%	28	10
PS-I	3	29	83%	7%	11	4
PS-C	3	23	65%	4%	20	17
PS-F	2	20	100%	0%	6	2
PS-H	5	17	23% (4)	6%	16	8
PS-E	4	11	73%	0%	8	4
PS-L	5	10	40% (2)	0% (2)	12	9
PS-G	3	7	86%	0%	7	4
PS-U	5	6	33% (3)	0% (2)	6	1
PS-O	3	5	60%	0%	6	6
PS-A	6	3	33% (3)	0% (3)	4	4
Median	4	26	52%	3%	11.5	7

Note: * If more than one student had the highest or lowest percentage of interactive events, the number of students is denoted in parentheses.

Based on this analysis, I wanted to know if the number of interactive events for the most active student in each student group was related to the number of peer-to-peer message units coded as collaboration (i.e., if there was a higher number of interactive events from one student, would the number of collaborative message units be higher or lower?). A correlational analysis revealed that there was a significant correlation (r (17) = .910, $p < .001$) between the number of interactive events for the most active students (M=24.13, SD=40.42) and the number of peer-to-peer message units coded as collaboration (M=13.17, SD=18.49), although there was no such correlation (r (16) = .330, $p = .195$) between the number of interactive events for the most active students (M=15.10, SD=13.31) and the number of peer-to-peer message units coded as collaboration (M=9.18, SD=7.67) once the results from group PS-D, an outlier in this analysis, were removed. A subsequent analysis confirmed that there was no correlation (r

(17) = -.380, p = .120) between the percentage of interactive events for the most active students (M=53.722, SD=21.378) and peer-to-peer message units coded as collaboration (M=13.17, SD=18.49). The distribution of interactive log events amount the student group members was therefore not an influential factor regarding whether students' basic interactions within LMS could be characterized as collaborative.

The data from the LMS event logs highlighted two potential factors influencing students' basic interactions and whether they could be further distinguished as collaboration: 1) the percentage of total interactive log events compared to content sharing log events and 2) the distribution of interactive log events among the student group members. Neither potential factor was significantly correlated with the number of peer-to-peer messages coded as collaboration.

4.4.3 Online Student Surveys

4.4.3.1 Face-to-Face Meetings

Students were asked in the second survey to report how often they met face-to-face (see Table 27). Over three quarters (82%) of students replied that they met face-to-face at least once every week suggesting that the LMS project site use was not a substitute for meeting.

Table 27: How Often Students Reported Meeting Face-to-Face

Never	Few times a month	Once a week	Few times a week
2% (n=1)	16% (n=7)	52% (n=22)	30% (n=13)

In addition to reporting how often they met face-to-face as a group, students were asked to explain what they discussed at those meetings and why they conducted those meetings face-to-face instead of online within the project site (52 total comments). Most of the students (n=47) replied that they divided work or went over certain portions of the grant proposal during their face-to-face meetings, and that they did so because it was easier than meeting online, as demonstrated in the examples below:

> [PQ3]: We'd talk about relevant papers we found, about what each of us had got done so far and what needed to be done. … It seems easier to communicate ideas in person, it's easier to get the point across of what we're trying to say.

> [PK4]: During face-to-face meetings we discussed) division of tasks between group members, progress on tasks from previous weeks, required progress to be made before our next meeting. … (The) speed of discussion and level of comprehension are both improved in person. In addition, face-to-face contact allows our group members to know that we are all focused on the task at hand.

Also, students were asked in the first survey where they lived in relation to the university in order to determine how easy it might be for students to meet face-to-face outside of their normal class sessions (see Table 28). The majority (87%) of students responded that they lived either in university-owned housing or within walking distance of campus.

Table 28: Students' Living Location in Relation to the University

In University-Owned Housing	Within Walking Distance of Campus	1-10 Miles Away From Campus	More Than 20 Miles Away From Campus
22% (n=15)	64% (n=43)	12% (n=8)	2% (n=1)

It was relatively easy for students to meet face-to-face as the majority of students lived close to the campus and to each other. The majority of students reported meeting face-to-face at least once a week, and their qualitative comments indicate that they actively discussed research papers, dividing tasks, and other collaborative topics at those face-to-face sessions. Such activity may have made collaboration within the LMS environment redundant and therefore unnecessary.

4.4.3.2 Benefits of Using Project Sites

Students were asked in the second survey to rate several potential benefits of LMS project sites on a 5-point Likert scale from 1="Strongly Disagree" to 5="Strongly

Agree" (see Table 29). The highest rated benefit was convenience (4.61), while the lowest rated benefit was improving learning (3.41).

Table 29: Student Ratings of Value of Benefits of Using Project Sites

"Using project sites is valuable for…"	n	Mean	SD
Accessing material any time, from any location (convenience)	41	4.61	.703
Saving me time (efficiency)	41	4.34	.693
Managing my project-related activities	40	4.20	.723
Improving my communication with other project site participants	41	3.80	.872
Improving other project site participants' communication with me	41	3.78	.909
Improving my learning	41	3.41	.836

After rating each individual benefit, students were prompted to select one as the *most* valuable benefit of using project sites (see Table 30). Over three-quarters (76%) of students chose the benefit related to the convenience of accessing material at any time and from any location. None of the students chose the benefits related to improving their learning or improving communication from other students.

Table 30: Student Responses About Most Valuable Benefit of Using Project Sites

Accessing material any time, from any location (convenience)	Saving me time (efficiency)	Managing my project-related activities	Improving my communication with other project site participants
76% (n=31)	7% (n=3)	10% (n=4)	7% (n=3)

These results show that students rated LMS benefits related to convenience and efficiency more highly than benefits related to communication and learning. When forced to choose just one benefit, the vast majority of students (76%) chose convenience, only a few students (7%) chose a benefit related to communication, and none selected learning benefits. These data show that while students may use the LMS to interact with their group members, they value the convenience and efficiency benefits of these systems far more than communication benefits, which might be more directly tied to collaboration and knowledge construction forms of peer interaction.

4.4.3.3 Student Perceptions of LMS Impact on Their Course Project

Related to the analysis of LMS benefits above, students who completed the second survey were asked to rate their agreement with several statements on a 5-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree. The statements were related to communication, learning, and overall success of the course project due to their LMS use (see Table 31). The highest rated statement was about the project site helping communication with group members (4.19). The lowest rated statement was about the grant project receiving a higher grade because of project site use (3.45). The low rating for project site use affecting grades is consistent with a statistical analysis that found no correlation (r (49) = -.140, p = .327) between grant proposal grades (M=93.96, SD=6.200) and project site use (M=.80, SD=.404).

Table 31: Student Responses About LMS Relationship to Their Grant Proposal Groups

Statement	n	Mean	SD
Using a project site helped me communicate with my other group members	43	4.19	.699
My NIH grant proposal assignment was more successful because my group used a project site	43	4.00	.845
Using a project site helped me learn from my other group members	43	3.60	.760
My NIH grant proposal assignment received a higher grade because my group used a project site	42	3.45	1.017

These results are important because they show that while students did not highly rate communication with other group members as a benefit of using LMS, they did agree that using the LMS helped them communicate with their fellow students. However, students were less sure about LMS helping them learn from other students, which is similar to the results from the benefits analysis.

4.4.3.4 Student Group Members Working Together

I also wanted to know how well groups worked together as this may have been a factor influencing students' ability to collaborate with each other. Using a 5-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree, students were asked if their group worked well together. The majority (90%, n=51) of students answered Agree or Strongly

Agree. When asked if the work was evenly distributed, a majority of students (67%, n=51) answered Agree or Strongly Agree, but there were several students (22%) who also answered Disagree or Strongly Disagree.

Students were also asked to estimate the percent effort they and their group members gave for the overall NIH grant proposal assignment. I noticed a difference for these effort estimations depending on how students' answered the survey item that asked if the work within their group was evenly distributed. The students who answered Disagree or Strongly Disagree to the survey item about evenly distributed work had a mean estimation of 69% for their group members' effort and 85% for their own effort. For the students who answered Agree or Strongly Agree to the survey item about evenly distributed work, the means were 94% for their group members' effort and 92% for their own effort. There was therefore a strong correlation (r (50) = .616, p < .001) between the survey items about work being evenly distributed (M=3.63, SD=1.131) and the estimation of other group members' effort (M=86.47, SD=18.033). This suggests that when students felt that the work was not evenly distributed, they believed that they put in more effort than their group members. However, there was no correlation (r (14) = -.077 p = .784) between the survey item about work being evenly distributed for groups with peer-to-peer messages coded as collaboration (M=3.29, SD=1.04) and the number of messages coded as collaboration (M=15.33, SD=19.61). Based on this quantitative analysis, students' perceptions of the distribution of group work were not influential factors regarding whether students' basic interactions within LMS could be characterized as collaborative.

In order to better understand students' answers about the effort percentages, I asked them to explain their answers. For example, a student from group PS-L thought that all of their group members gave equal amounts of effort:

> [PL5]:I think that everyone worked pretty equally on the project. We played to our strengths and I think it helped allot. We were a lot more efficient than I have been with other groups in the past, and people were willing to do work and make sure that it got done on time.

Other students did not feel that some of their group members gave the same amount of effort as others, as seen in this example from a group N-EE student:

> [NEE1]: I felt like one of my group members did not take initiative on her parts of the project, instead waited for the rest of us to tell her exactly what and how to do everything. This was frustrating for those of us who were giving our full efforts.

And in some cases, students thought that while their group members did complete their assigned portions of the grant proposal assignment, the informant ended up doing more work related to research or editing:

> [PH1]: Because I came up with the idea, I knew and understand the most about this topic. Therefore, I spent a lot of time editing and writing the whole grant. My group members also completed their assigned sections well and on time, but some parts needed major revisions due to misunderstanding of the topics.

4.4.3.5 Other Factors

Correlational analyses of the survey data did not reveal any other factors affecting students' online peer interaction. Computer expertise (M=2.21, SD=.606) was not correlated ($r(42)=.145$, $p=.361$; $r(42)=.023$, $p=.887$) with how students felt their project sites helped them communicate (M=4.19, SD=.699) or learn (M=3.60, SD=.760) from other group members. Additionally, prior group experience (M=2.88, SD=1.351) was also not related ($r(43)=.075$, $p=.634$; $r(43)=-.088$, $p=.574$) to how students felt their project sites helped them communicate or learn from other group members. Thus, computer expertise and prior group experience were not influential factors regarding whether students' basic interactions within LMS could be characterized as collaborative.

4.4.3.6 Online Surveys Summary

Overall, the online surveys illuminated a number of possible factors that may have influenced whether the basic interactions between students were also collaborative.

Face-to-face meetings, as previously mentioned in the peer-to-peer messages (see above), were very popular and over three quarters (81%) of students replied that they met face-to-face at least once every week. Convenience, efficiency, and managing activities were three highly rated benefits of LMS project site use and 93% of students rated them as the most valuable. Students did think that, overall, the LMS helped them communicate with their group members, although it is not clear if their preference for convenience and efficiency benefits influenced the distinction of the different forms of peer interaction.

4.4.4 Student Focus Group Interviews

4.4.4.1 Face-to-Face Meetings

As in the peer-to-peer messages and the online surveys (see above), students participating in the focus group interviews also mentioned their face-to-face meetings. Students from group PS-O explained that they used these meetings mainly to divide work and clarify areas that were central to their grant proposal assignment:

> [PS-O Student 1]: We had lab twice a week.
>
> Steven: You were all in the same lab section?
>
> [PS-O Student 1]: Yeah. So that helps because we have a lot of down time so we can converse about things, bounce things off each other then. And then as the project got closer we kind of met more and more often.
>
> Steven: And then what kinds of things did you talk about when you met face-to-face?
>
> [PS-O Student 1]: Mostly just divvying up the work.
>
> [PS-O Student 2]: Clarifying something.
>
> [PS-O Student 1]: Clarifying the work especially. Kind of sometimes I guess seeing if we were still on track with things or if we were being too ambitious.

> [PS-O Student 2]: Yeah it was basically just like a place where we were definitely focused. We met because it was more focused instead of trying to have conversations in the middle of experiments during the class and so forth.

4.4.4.2 Student Group Members Working Together

Students also discussed some of the tension between their group members during the focus group interviews. One focus group interview ended up being a single student interview because the other two students did not show up for the interview. He discussed his difficulty with his group members' use of the project site and the research they conducted for the project:

> [PC1]: [PC3] just sent a number of email, link, non-descript links to papers in an email which I found kind of frustrating. ... Eventually the ones that he actually used got uploaded but I skimmed through some of them and some of them didn't really seem relative and it was kind of irritating because the way we had been using the Resources site was allowing us to easily see is this relevant to what I'm working on, what's the purpose of this paper.

The same student also explained that he was the only group member committed to using the LMS project site:

> [PC1]: …the others weren't really using it and there were only two other people in the group so it was typically just as easy or easier to just respond to emails or compose emails to the two other members.

In an example from a different group, a student from PS-Q discussed times of low productivity and how the group worked through them:

> [PS-Q Student]: We know each other from fairly well from the clubs and stuff that we're in together so when we meet we're fairly productive for a while and then we kind of lose productivity so that's probably our biggest fault as a group because then we start hanging out and just watching YouTube videos and laughing but we haven't had like tension that I've seen or any arguments. If we've disagreed on where we thought the direction was we just kind of like discussed

> like oh but I found this paper that kind of said this so it kind of made me feel like this has already been done or maybe this wouldn't really work as well so maybe we should try to do that.

Overall, the focus group interviews illuminated two factors also raised by the online surveys: face-to-face meetings and how well group members worked together. Both of these factors could possibly have influenced whether students' online peer interaction moved from basic interaction to collaboration.

4.4.5 Instructor Interviews

During the start-of-term interview, the instructor stated that groups could not disband or change membership after the proposal summary was turned in. He stated that his policy for group membership is a kind of contractual agreement, and students are bound to honor that agreement despite any disagreements:

> [Instructor]: Most often each term there's one or two groups that come to me saying they can't work together or it's just not working out. So it's the rule versus the exception where out of 140 students or so that I have now a couple of groups will have a melt down and it's most often bigger groups but it can be smaller groups like a pair of people and I always tell them the same thing: You agreed to this. It's a contractual arrangement. You have to find a way to work. I'm not going to allow you to work individually so if you turn in separate projects I'm only going to accept one project and I'll determine which project that is and then some of you are going to get zeros and the others are going to get a grade so when you leave my office or you leave the lab you have to go somewhere and find a way to work together. They know this way before the start. They hear it several times. It's in the course pack described as such that when you turn in your rough draft is when the contractual arrangement has started.

The instructor reasoned his decision by stating that the mock NIH grant proposal assignment was designed to reflect the real research settings in biology:

> [Instructor]: In a research setting often it's a team oriented effort in industry as well as academia so you'll work with other principle

> investigators from other departments, other universities, other countries, your post doc or graduate students or technicians so it's a team effort. … If you're hired by Pfizer you're told to work with this group of 50 people. You don't have a choice, you can't say I don't like that girl and I don't like that guy, I'm not working with them. You must work with them. You have to find a way. So (students) tell me they want to work as a group, if they have some fights they have to get over it. They have to find a way to work together because research is most successful as a team effort.

The instructor also emphasized that he believes that course assignments in which students are required to work together not only replicates the authentic collaborative nature of biology research settings but that biological research, overall, is "most successful as a team effort." Nevertheless, the instructors' policy for the grant proposal group membership could have potentially prevented their group from working past conflict if the student group had difficulty working together.

4.4.6 Summary

The results presented in this section show that there were many potential factors that may have influenced whether students' online basic interaction was also collaborative. While the data collected cannot identify all of the possible factors involved, the survey results identified some potential factors such as the high frequency of face-to-face meetings and the disparity between highly rated benefits compared to lower-rated benefits. Other possible factors identified by analysis of the data sources collected in this study were not significantly correlated with the number of peer-to-peer message units coded as collaboration in this dissertation study.

4.5 Research Sub-Question E: What Factors Influence Whether Student Collaboration Within LMS, if any, can be Characterized as Knowledge Construction?

In this study, peer interaction was distinguished as knowledge construction if the collaboration within a LMS tool between students resulted in new information transferred and retained from one student to another or a new understanding elicited by students through their collaborative interactions. However, identifying factors may be difficult as just ten message units (out of 397 total) were coded as knowledge construction, and seven of those came from one student group (PS-D). Despite this difficulty, exploring the data sources collected in this study helped identify several potential factors.

In order to answer this research sub-question, I utilized three data sources:

- I explored possible patterns within the peer-to-peer message units in order to help identify any potential factors.
- The event logs were used to look at the groups that produced message units identified as knowledge construction and compare the overall LMS use for these groups to all other student groups.
- In the focus group interviews, students were asked to comment about any problems they had with the LMS technology. These technological problems may have inhibited knowledge construction.

4.5.1 LMS Peer-to-Peer Message Units

I reviewed each of the ten peer-to-peer message units coded as knowledge construction and put each unit in context to see if any patterns emerged to indicate any obvious factors. Six of the ten message units came from interactive chat sessions where students were directly questioning and replying to each other and building new group knowledge from their individual perspectives. Additionally, two more message units were from Announcement messages that directly replied to previous announcement messages. Therefore, direct (messages that explicitly reference a previously posted message) rather than indirect (messages that do not explicitly reference a previously posted message) collaboration with other group members may be a possible factor influencing knowledge construction within LMS, although the other two message units coded as knowledge construction show that not all indirect collaboration is prevented from reaching this third type of peer interaction.

4.5.2 LMS Event Log Data

When analyzing the ten peer-to-peer message units coded as knowledge construction, the event log data shows that seven of those message units came from one student group, PS-D, who used several different tools within their project site quite heavily (e.g., Resources, Chat, Announcements). The other three groups, PS-J, PS-N, and PS-P, all had fairly active project sites, and all used Resources and at least one interactive tool. When compared to all other groups overall, these four groups had far more Announcements, Chat, Resources, and site login / logout events. Thus, using the project site in higher amounts of activity, compared to other student groups, might be a necessary factor for collaboration to lead to knowledge construction (or vice versa). To test this assertion, an initial analysis revealed a correlation (r (17) = .971, $p < .001$) between the number of interactive events for each student group (M=59.167, SD=135.094) and the number of peer-to-peer message units coded as knowledge construction (M=.556, SD=1.653). However, a subsequent analysis removed the results for group PS-D and revealed that there was no correlation (r (16) = .321, $p = .209$) between the number of interactive events (M=27.824, SD=24.552) and message units coded as knowledge construction (M=.177, SD=.393) after the removal of this outlier group.

Thus, many student groups extensively used their project sites throughout the term yet did not have any peer-to-peer message units coded as knowledge construction. For example, both groups PS-K and PS-M used the Announcements and Chat tools in addition to the Resources tool throughout the semester, but none of their messages were coded as knowledge construction. Higher amounts of LMS use alone does not therefore necessarily produce new knowledge evidenced in online peer communications. However, there is no evidence from this study that knowledge construction is possible without high levels of LMS use.

4.5.3 Focus Group Interviews

4.5.3.1 Problems Using LMS Technology

When discussing their use of various tools within their LMS project sites, several student groups mentioned problems that they experienced with the technology that might have prevented their online collaboration from being distinguished as knowledge construction. For example, a student from group PS-D, a group that used the chat room extensively and had several messages coded as knowledge construction, nevertheless mentioned that they experienced a temporal delay that students found very annoying:

> [PS-D Student]: Or like [PD4] would ask a question and then [PD5] will answer it and I was in mid answering and I'm like well should I continue to answer it because a new question has already been posed and so it's a little better in person if you can.

Other students also had problems with the Resources tool. When a user in the LMS uploads a new version of a document, it overwrites the previous document. Students expressed problems with this functionality because multiple people would be working on the document and then accidentally overwrite each other's work. Two students from group PS-I explained:

> [PS-I Student 1]: Well we both download the document and then we would both write separate parts then maybe I would upload mine and then she would upload hers overwriting mine or something like that.
>
> [PS-I Student 2]: Yeah so we had to be really careful. So during the meetings we would like wait did you just upload that? Or someone would send the section they had written in the email to that person and then that person would copy and paste into their document and then they would post it to CTools.

4.5.3.2 Limits of LMS Technology

Another possible factor, related to problems with technology, are the limits of said technology. If the technology does not allow the user to accomplish a desired function, the user will either modify their original plans or find another way to achieve their goals (Rick & Guzdial, 2006). In terms of LMS technology, students commented that they reached a point where the technology inhibited their collaboration, and they resorted back to face-to-face meetings in order to share information and possibly construct new knowledge. For example, a student from group PS-P explained why face-to-face meetings are easier for communication:

> [PS-P Student]: It's easier to communicate with someone if they're there physically in person because you can like physically show them a document or like talk to them or if you want to get you know it's like bonding if you're working on a project and everyone's there, it just somehow makes it…there's more of a synergy then like if everyone's going to be on the chat everyone's going to be available at that time so you might as well just meet in person.

In another example, two students from group PS-D stated that biological concepts are often better explained visually and the LMS does not afford that kind of visual collaboration easily:

> [PS-D Student 1]: Lots of biology can be explained visually and if you draw a picture on the board you can explain a concept fairly…to make it accessible. If I was going to explain how (a concept) works that's where lots of paragraphs make it very clear and concise whereas on the board I can just draw a couple of sketches and it's clear. So if there was a doodle function on (the project site) that could help but without the visual context biology would be kind of hard.

> [PS-D Student 2]: Even if there was a doodle function I would still say let's meet and we'll talk about it. It takes too long and it's not as clear (online).

The comments from the focus group interviews show that if students are spending their group time worrying about problems with the technology or struggling to do things that the technology cannot accomplish, it may inhibit their ability to use the particular technological tools to construct new knowledge.

4.5.4 Summary

There were several possible factors found in the data sources that may have influenced whether students could progress from collaboration to knowledge construction within their LMS project sites. One of these factors, as discovered in the analysis of the peer-to-peer message units, might be direct (rather than indirect) response to other students' peer interactions. Also, problems with or limits of the LMS technology could have inhibited knowledge construction according to students' comments in the focus group interviews. As explained in the previous research sub-question, this list of potential factors is not meant to be exhaustive but rather highlight a few possible factors as indicated by the collected data sources in this study. Furthermore, the factors described as possibly influencing students' ability to progress from basic interaction to collaboration may have also influenced students' ability to progress from collaboration to knowledge construction.

4.6 Summary of Study Results

The results presented in this chapter serve to answer the sub-questions related to the overall research question for this study: How do students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project? The first research sub-question thus investigated what types of peer interactions took place within the LMS. Coding and analysis of the peer-to-peer message units revealed that just over one third (35%) of students' online communication was identified by the code "basic interaction." The remaining online communication was coded primarily as collaboration (60%) with only as small portion of the online communication (3%) displayed the characteristics of knowledge construction. Students felt that sharing documents and messages were the most useful activities via the LMS, according to the online surveys. Overall, some student groups were engaged in a wide variety of peer interactions via their LMS project sites.

The second research sub-question investigated which tools students used to interact within their LMS project sites and why. The most used tool, overall, was the Resources tool, and the most-used tool for the peer-to-peer message units was Announcements. The Chat, Discussion, and Email Archive tools were also used, although not as extensively. Students rated the Resources and Announcements tools the most useful for collaboration in the online surveys. Furthermore, their ratings of these tools increased throughout the semester, while ratings of all other LMS tools decreased.

A third research sub-question investigated how often students used the LMS to interact over time. Analysis of the peer-to-peer message units revealed a pattern of peer interaction that was clustered around the two course milestones, a grant proposal summary due in early February and the final grant proposal due in early April. The event logs revealed a similar pattern of use for both the Resources tool and the interactive tools (e.g., Announcements, Chat, Discussion, and Email Archive) overall. Students' responses to the online surveys also show that students reported that their use of the LMS increased throughout the semester.

The final two research sub-questions investigated possible factors that may have influenced whether the basic interaction between students was collaborative and factors that may have influenced whether those collaborations could also be distinguished as knowledge construction. There were a several possible factors discovered in the data sources including the frequency of face-to-face meetings and possible problems with or limits of the LMS technology to adequately support all of the students' peer interactions.

Overall, the peer-to-peer message units, log event data, online survey results, focus group interviews, and instructor interviews helped create a vibrant story of how undergraduate students used the LMS to interact, collaborate, and construct knowledge within the context of a course-related project. In the next chapter, I will discuss how the findings presented in this chapter answer the overarching research question and also provide recommendations for improving LMS design for student projects.

CHAPTER 5

DISCUSSION

This dissertation study investigated how students' use of learning management system (LMS) project sites facilitated their interaction, collaboration, and knowledge construction within the context of a term-long course project, a mock NIH grant proposal. In this chapter, I discuss the results presented in Chapter 4, the implications of this study, limitations of this study, and future research possibilities.

5.1 Analysis of Results

The overall research question driving this study was: How do students use LMS to interact, collaborate and construct knowledge within the context of a course-related project? In this section of the chapter, I discuss a few major findings from the results of the research sub-questions that serve to answer the overall research question. I then explain how these major findings are evidenced and played out within the experience of the most active student group from this study. I conclude this section of the chapter with a short discussion of what LMS truly help students "manage:" learning or work.

<u>5.1.1 Basic Interaction and Collaboration Between Students Within the LMS</u>

At the outset of this study, I hoped that students would embrace the LMS and use the technology not only to manage the logistics of their group projects but also to discuss and debate the specifics of their collaborative work, similar to the adoption pattern of LMS discussed in some LMS-related literature (e.g., Black, Beck, Dawson, Jinks, & DiPietro, 2007). The results show that every group that used the interactive LMS tools had at least one collaborative exchange on their site, and about half of those groups had more collaborative messages than interactive messages. Furthermore, students responded favorably in the online surveys when asked about the usefulness of activities conducted within the LMS, such as posting and accessing documents and other materials and sending and receiving messages to other group members.

Papstergiou (2006) argued that LMS lack the flexibility to make collaboration practical and straightforward so that students can easily share their ideas. However, some of the findings from this dissertation study appear to refute that argument and instead indicate that some students were able to use their LMS project sites effectively to manage their mock NIH grant proposal assignment and also to collaborate about many of the topics and concepts within that assignment. The findings from this dissertation study demonstrate that LMS technology is not as simplistic as Papstergiou's argument would indicate. Some students may be limited by the lack of flexibility of the kind of communication possible within LMS and not able to collaborate, while others may be able to work past these limitations and find ways to use the LMS to collaborate, as many student groups did in this dissertation study. Whether the findings from this dissertation study that indicate that many groups were able to collaborate are an artifact of the LMS technology itself, an artifact of some groups' internal dynamics, or some combination of the two is unknown and deserves further research in future studies. Furthermore, LMS designers might benefit from examining the kinds of users who are able to work past the inherent limitations within the technology and collaborate within their groups in order to learn how to improve the overall design for all users to be able to easily share their ideas within the LMS.

5.1.2 A Lack of Knowledge Construction Evidence Within the LMS

Despite the abundance of basic interaction and collaboration found within students' peer-to-peer message units in the LMS, there was very little evidence in the online communications of students actually transferring and retaining new information or eliciting new understandings. That is not to say that students did not learn anything from each other or from this course assignment, only that evidence of such learning was not found in the majority of messages within the LMS. It is also important to note that within the ten message units coded as knowledge construction, there was a significantly higher word count than messages coded as basic interaction and collaboration. This could indicate that students needed longer peer interactions in order to begin learning from each other. Encouraging and supporting these kinds of longer peer interactions could potentially facilitate greater amounts of knowledge construction within LMS.

5.1.3 The Impact of Face-to-Face Meetings

As indicated in Chapter 4, there were several possible factors that may have influenced whether students' online basic interaction could be further distinguished as collaboration or knowledge construction. Of all of these factors, I believe that the high rate of face-to-face meetings may have been the most dominant. The residential nature of the university in this study was likely a contributing factor; Over 86% of survey respondents (n=67) indicated that they either lived in campus-owned housing or within walking distance of campus. Students generally reported that meeting together was simply easier than using the various communication tools within the LMS, and they met to discuss dividing the work load, clarifying biological concepts, and other issues related to their course assignment. But would students have collaborated more if they had met face-to-face less and instead met online within the LMS? Recent research has found that online groups, compared to face-to-face groups, have engaged in broader, more complex, and more cognitively challenging discussions, and that online groups delivered more complete reports and made decisions of higher quality (Benbunan-Fich, Hiltz, & Turoff, 2003; Fjermestad, 2004). However, the students in these studies were either required to use online technologies by their instructor or were otherwise incentivized. In this dissertation study, when students had freedom to choose how they wanted to meet, they claimed it was simply easier and more productive to meet face-to-face, demonstrating that they valued "collocated work" opportunities over online work opportunities (Olson, Teasley, Covi, & Olson, 2002).

In terms of the design of computer-mediated communication tools, Jonassen and Kwon (2001) argued that ill-structured tasks are best suited to open-ended environments, while well-defined tasks are better suited to more rigid environments. However, if the online environment places too many limitations on students' ability to interact normally, or as they would in a face-to-face situation, then the advantage of the online environment is quickly diminished, if not completely removed (Tutty & Klein, 2008). While the mock NIH grant proposal assignment was a well-defined task overall, the process for accomplishing that task was not structured as students were responsible for their own group without any instructor mediation. Therefore, while the open-ended nature of LMS interactive tools was possibly a good fit for the student groups in this study, the design of the tools may have inhibited some of the groups' natural interactions. Since students could easily meet face-to-face for group collaboration, students may have chosen to do so in order to avoid changing their peer interaction patterns to accommodate the LMS technology. In order to accommodate students' normal peer interaction patterns and assure a better "task-technology fit" (Jarvenpaa, 1989), the interactive tools within LMS should either be redesigned in order to reduce the tension between face-to-face interaction patterns and LMS technology, include more face-to-face interaction components (e.g., voice, facial expression, avatars, etc.), or some combination or blending of both of these options. LMS designers can draw on a wide variety of research in order to effectively implement voice (e.g., Pan & Sullivan, 2005), video (e.g., Tomadaki, Quick, & Scott, 2008), affective computing agents (e.g., Klein, Moon, & Picard, 2002), and other relevant technologies in order to improve the online peer interaction environment for students.

5.1.4 Problems and Limitations of LMS Technology

In addition to the high rate of face-to-face meetings, I believe that the problems and limits of the LMS technology, as described by the students in this study, also influenced whether students' online interaction could be defined as collaboration or knowledge construction. Basic problems with the technology including time delays in the Chat tool and overwriting of files in the Resources tool are problematic when trying to encourage students to use a technology that, while they are experienced with it from a student perspective, is still new to them in terms of group work. These types of problems can be a barrier for effective use of learning management systems for instructors and students (Dutton et al., 2003) and for groups of students using LMS project sites (Cleary & Marcus-Quinn, 2008). As student project use becomes more common in LMS, designers need to address issues of students in their own independent LMS sites in addition to the issues of instructors in more traditional course-based kinds of LMS use.

Students also indicated that the technology did not provide them with the features and supports they needed to adequately collaborate at higher levels, such as visually explaining a concept, or to achieve the same kinds of feedback that are achieved in face-to-face situations. It is this lack of functionality that is likely to have been the reason why there was no increase in the number of peer-to-peer message units coded as collaboration or knowledge construction regardless of the distribution between content sharing and interactive log events or distribution of activity among group members. Therefore, instead of struggling to have collaboration and knowledge construction within a system without the necessary technological supports, students instead reverted to face-to-face meetings.

In order to adequately support online collaboration and knowledge construction, the technology must be able to support three distinct educational processes: 1) idea generating and gathering, 2) idea linking, organization, and progress, and 3) idea structuring and convergence (Harasim, 1990). Many of the student groups in this dissertation study appeared to use the LMS in order to generate and gather ideas, and some were also able to link and organize those ideas, but very few were able to use the LMS technology as an environment or mechanism for structuring and achieving convergence about their ideas related to their group assignment. What is not known is whether the LMS technology supported these educational processes and if students achieved them outside of the technology. I surmise that the students' motivation to do well on their mock NIH grant proposal motivated them to use the LMS for a variety of educational processes, such as those described by Harasim (1990), even though they were not explicitly designed into the LMS.

Although online technologies are expected to modify communication as compared to face-to-face situations, computer-supported collaborative learning systems can facilitate activities that generate multiple viewpoints and patterns of reasoning that challenge the cognitive skills of each student group member (Brandon & Hollingshead, 1999). Furthermore, online technology can support creative problem-solving through a variety of processes including visualization (e.g., organizational trees, scatter-plots, etc.), free association (e.g., concept maps, drawing, etc.), and simulation (K. A. Butler & Lumpe, 2008; Shneiderman, 1999; Shneiderman & Plaisant, 2005). However, the technology must be designed so that the student understands what features are salient to the task of collaborative knowledge construction (Norman, 1990). While LMS does have many of the basic tools to support students' collaborative construction of knowledge, those tools lack the necessary features to guide, facilitate, and scaffold students successfully through the knowledge construction process. There have been some who have advocated and begun initial designs for including higher-order reasoning and creative problem-solving capabilities within LMS (Dag & Erkan, 2007; Venkatesh, Shaw, Dicks, Lowerison, Zhang & Sanjakdar, 2007). Open source LMS such as Moodle and Sakai are well-suited to implement these features in the future in order to more successfully support collaboration and knowledge construction within LMS, particularly since the communities supporting these systems are able to integrate learning theories into a continually evolving online product (Fischer, 1999).

5.1.5 The Case of Student Group PS-D: Why Were They the One Student Group to Have Evidence of Knowledge Construction Within the LMS?

Of the ten message units coded as knowledge construction, seven were from one student group (PS-D). Although more evidence of knowledge construction within the LMS would have been preferable, it is relevant to further detail the circumstances of this particular student group in order to better understand how they were able to utilize the LMS to produce new knowledge when almost every other student group in this study did not.

Group PS-D was comprised of six students, four male and two female. Five of the students were Senior MCDB majors, and the sixth was a Junior pre-med Biomedical Engineering major. Of the four students who answered the online surveys, all lived within walking distance of campus, and all had previously used LMS project sites. All six students were in the same laboratory section within the MCDB course. The topic of this group's mock NIH grant proposal project was using mice to investigate the hygiene hypothesis and related asthma rates in urban vs. suburban environments. The group received an initial grade of 98 (out of 100) on the grant proposal assignment and received a 99 (out of 100) after a re-grade submission.

[PD3] created the LMS project site on January 27th and activated the Announcements, Chat, Discussion, Email Archive, Resources, and Schedule tools. A breakdown of activity within these tools by the six students is described in Table 32 below. Overall, [PD3] was the most active student on the site, with 26% of the total activity, while [PD5] was the least active student on the site, with 10% of the activity. The most used tool was Resources, with 49% of all site activity, and the Chat tool was the most used interactive tool, with 26% of all site activity (percentages based on total number of events per tool divided by the total number of events for the LMS project site).

Table 32: Number of Tool Events for Student Group PS-D by Event Type and Corresponding Percentages by Student

Category / Tool	Event Type	Number of Events	PD1	PD2	PD3	PD4	PD5	PD6
Site Login	Login	454	21%	11%	26%	16%	8%	18%
Site Maintenance	Revise Settings	4	0%	0%	100%	0%	0%	0%
Announcements	Add	39	18%	0%	43%	18%	0%	21%
	Revise	4	0%	0%	75%	25%	0%	0%
Chat	Add	535	15%	11%	17%	31%	19%	7%
Discussion	Add	12	0%	0%	50%	42%	0%	8%
	Revise	1	0%	0%	100%	0%	0%	0%
Email Archive	Add	1	100%	0%	0%	0%	0%	0%
Resources	Add	200	5%	2%	19%	58%	6%	10%
	Access	749	26%	16%	31%	7%	7%	13%
	Delete	25	4%	8%	16%	56%	16%	0%
	Revise	54	15%	13%	31%	15%	9%	17%
Schedule	Add	3	0%	0%	0%	100%	0%	0%
	Revise	3	0%	0%	0%	100%	0%	0%
TOTAL		2,084	19%	12%	26%	21%	10%	12%

The first substantial use of the LMS project site for group PS-D was to discuss and upload materials for a "mini project" that was part of the laboratory section within the MCDB course. Following this use, the group discussed and uploaded materials related to the mock NIH grant proposal summary draft. A large amount of this discussion took place during an hour-long online chat session on February 3rd involving all six group members and comprising 38 message units, 10 (26%) of which were coded as basic interaction, 24 (63%) as collaboration, and 4 (11%) as knowledge construction. The knowledge construction message units discussed the relationship of RNA, Parkinson's disease, and Huntington's disease and the various genes, biological processes, and related concepts. The group utilized the chat tool in five additional sessions on February 6th, 10th, 11th, 12th, and March 26th. The March 26th chat session generated another message unit coded as knowledge construction that discussed flow cytometry. The other two message units coded as knowledge construction occurred via the Discussion tool (a January 28th post about a gene known as CD80) and the Announcements tool (a April 2nd post about definitions of different exposures). Thus, group PS-D was able to use a variety of LMS tools to collaborate and construct knowledge about the biological concepts within their mock NIH grant proposal assignment.

In addition to the online messages collected from group PS-D, these students uploaded or added 200 different Resource items and downloaded or accessed them nearly 750 times. Organized into eight main folders and several subfolders, the bulk of these items were research articles or web links to online resources related to the groups' mock NIH grant proposal. The group also used the Resources tool to manage presentations and pictures for several different "mini projects" that were part of the laboratory section within the MCDB course. The evidence from the Resources tool as well as the online messages indicates that this group used the LMS to interact not only about their mock NIH grant proposal assignment, but also about other course projects and assignments.

One of the possible reasons that this group was able to construct knowledge within the LMS tools is because they had greater difficulty meeting face-to-face than other student groups in this study. In the focus group interview, students specifically mentioned being out of town or unable to meet face-to-face and thus meeting in the chat tool for group meetings (such as the hour long chat session on February 3rd). However, the group did also mention that they experienced technical problems and limitations with the chat tool and ultimately decided to meet more regularly face-to-face so they could have a "more complex" conversation, be able to "multi-task," and be able to draw diagrams of different biological concepts collaboratively. These comments are reminiscent of comments from other student groups' comments about face-to-face meetings and the limitations of the LMS technology. In essence, this group of students continued to evaluate the LMS in terms of a costs and benefits. Early in the term, when the students were not collocated, the benefits of synchronous chat and central file management outweighed the costs of struggling with the technology's limitations. However, as the students required additional technological functionality that the LMS did not provide, the costs of using the LMS began to outweigh the benefits, and the group resorted to face-to-face meetings instead. Based on the comments from group PS-D's focus group interview, I hypothesize that the face-to-face meetings for this group generated many of the same kinds of collaboration and knowledge construction interactions witnessed online within the LMS.

There are several other possible reasons why this group was able to show evidence, albeit minimal, of knowledge construction within LMS while other groups were not. First, the group initially embraced the LMS project site and committed to using the various interactive tools for their communication through the grant proposal summary deadline on February 7th. That commitment generated five of the seven message units coded as knowledge construction. Furthermore, despite their comments that they were frustrated and saw limitations within the technology, they saw enough benefits in the Resources and Announcements tools for managing their work that several group members, although not all, continued to use the interactive tools and generate additional message units, many coded as collaboration and two coded as knowledge construction. Beyond this commitment to the LMS, I surmise that this group was very experienced with group work as most students in this group were MCDB Seniors, and the Junior student was a pre-med biomedical engineering major, a program that includes several courses that require group work. This assumption is supported by the survey responses in which three of the group members strongly indicated that the group worked well together, the work was evenly distributed, and all members put in roughly equal amounts of effort. Overall, group PS-D heavily used the Announcements, Chat, and Resources tools to manage and communicate about their mock NIH grant proposal assignment and, by doing so, was one of the few groups to demonstrate online evidence of knowledge construction.

5.1.6 Are LMS Managing Learning or Managing Work?

LMS stands for learning *management* system. However, there does not seem to be much evidence in this dissertation study that the technology was, in fact, "managing" students' learning. This study sought to investigate how students use LMS to interact, collaborate, and construct knowledge within the context of a course-related project. Students were very successful in using the LMS to organize their face-to-face meetings, gather research materials, and share versions of their documents. Many students were also successful in using some of the interactive tools within LMS to collaborate about the different biological concepts and procedures within their mock NIH grant proposals. However, most students were not as successful in providing online evidence of construction of new knowledge, the majority of which was located within the peer interactions of Group PS-D. Therefore, are learning management systems really "managing" learning, or more effectively managing student work? Based on the evidence in this study, students' managerial and organizational goals were well suited for the LMS, particularly through the Resources and Announcements tools. However, students' learning goals were not as evident within the LMS and were likely handled in face-to-face meetings due to students' collocation to each other, the perceived ease of discourse in such meetings, and possibly also due to the problems and limitations of the LMS technology. As discussed above, LMS technology needs to be reexamined and redesigned with the realization that not all activities within these environments necessarily include the traditional instructor-student dynamic and must also support learning within small groups, such as the student groups described in this study.

5.2 Implications of This Study

There are several important implications of this study, as indicated by the above discussion about the results. Chief among these implications are improvements to LMS design to better support collaboration and knowledge construction. Furthermore, I provide some general suggestions for improving LMS design based on students' recommendations. I also discuss more literature-oriented implications of this study, such as providing a more student-oriented focus in LMS-related work and connecting LMS with other bodies of literature. Finally, I discuss implications of this work beyond the case study context.

5.2.1 Scaffolding Collaboration and Knowledge Construction Within LMS

As indicated in the introduction to this dissertation study, LMS have become nearly ubiquitous across higher education institutions (Browne et al., 2006; Hawkins & Rudy, 2008). Originally designed solely for the web-based management of course materials, LMS have been repurposed with a much wider agenda:

> "(LMS) are not only widely used for business or educational delivery of information purposes, but are also used to support online collaboration. There are an increasing number of tools and online environments emerging that are especially designed with affordances to support collaborative learning or knowledge building" (Resta & Laferrière, 2007, p. 75).

Much of the existing literature on LMS being used to support online collaboration has been in the context of courses where the instructor served as a mediator and organizer who structured students' online activities (e.g., Dougiamas & Taylor, 2003; Gaensler, 2004; Topper 2003). Within LMS course sites, the instructor typically creates the topics or prompts for online discussion and guides online collaboration in order to maintain a "shared conception" of the issues (Roschelle & Teasley, 1995) within the class members' discourse. However, in this study, students used their LMS project sites without any explicit monitoring, modeling, coaching, or guidance by their instructor and instead relied on their own prior experience with the technology as well as whatever existing affordances the technology provided (e.g., the online help tool within the LMS), which were very minimal. When students encounter the tools within LMS, they are presented with a blank canvas without any direction or suggested use by the system. At the same time, there is no instructor mediation within project sites. Therefore, students are responsible for their own use of the LMS tools and have the potential to establish a highly collaborative environment online that leads to successful sharing and building new knowledge. However, they are not likely to do so without adequate cognitive scaffolding (Wood et al., 1976). I therefore propose that LMS incorporate some basic scaffolds to facilitate student collaboration and knowledge construction for projects like the one investigated in this study.

The type of scaffolds I propose to incorporate within LMS are aimed at facilitating productive planning and monitoring of reflective practices and are one of many possible methods that can help students identify deficiencies in their cognition and improve their collective understanding of the concepts central to their groups' objective (Quintana et al., 2004; White & Frederiksen, 1998). It is also critical that these scaffolds fade over time so that the students can maintain control of their own learning (Collins et al., 1989). I believe that these kinds of scaffolds are a logical place to begin facilitating collaboration and knowledge construction within LMS. If successful, additional kinds of scaffolds may be possible within these systems.

What kinds of scaffolds should be implemented in LMS in order to adequately support collaborative knowledge construction? Although students in this dissertation study effectively shared and compared concepts and other information with each other, they did not often use the LMS to explore areas of disagreement, collaboratively negotiate the meaning of concepts, test hypotheses against facts or data, or apply newly constructed knowledge to other areas, all of which are significant stages of knowledge construction (Gunawardena, Lowe, & Anderson, 1997). Ge and Land (2004) argue that embedding question prompts in computer-supported learning environments may help students engage in deeper cognitive processing such as clarifying thinking, reorganizing information, correcting misconceptions, and developing new understanding. Prompts can also be used to help learners reflect, plan, and monitor their learning (Davis & Linn, 2000). Scripting and prompting approaches developed in research on collaborative learning assumed that these types of scaffolds could be faded because learners would internalize the script over time (e.g., O'Donnell & Dansereau, 1992; Palincsar & Brown, 1984). A variety of different types of collaboration scripts designed to scaffold online discussion have been implemented in previous CSCL environments including prompts or sentence starters (Nussbaum, Hartley, Sinatra, Reynolds, & Bendixen, 2002; Weinberger, 2003), buttons that open text boxes for specific speech acts (Baker & Lund, 1997; Hron, Hesse, Reinard, & Picard, 1997), and input text fields (Kollar, Fischer, & Slotta, 2005). However, scripts or prompts can also constrain collaboration if they are too restrictive and over-script students' cognitive processing and motivation (Cohen, 1994; Dillenbourg, 2002). Nevertheless, recent research has shown that prompts and scripts can help students collaborate and improve subsequent collaboration (Rummel & Spada, 2007) in both coarse-grained online activities (e.g., a small-group discussion) and fine-grained online activities (e.g., formulating a counter-argument) (Dillenbourg & Fischer, 2007).

Given the prior literature described above, minimal question prompts could be suggested along the side of interactive LMS tools like Announcements, Discussion, and Chat in order to stimulate more collaborative and knowledge construction interactions between students. The system could display procedural and elaborative prompts that fade automatically over time (Ge & Land, 2004) such as:

- An example of this is…
- Another reason that is good…
- What is a new example of… ?
- Why is that important… ?
- How does … affect… ?
- To do a good job on this project, we need to…

The LMS could also offer examples via pop-up windows of how students can structure their interactive tools via short sample conversations using prompts like the ones provided above or more detailed collaboration scripts that have been found to facilitate argumentative knowledge construction (Stegmann, Weinberger & Fischer, 2007). That way, students have examples of effective knowledge construction interaction as well as question prompts that allow them to apply the examples to their own context. Furthermore, prompts and example scripts can encourage students to have longer conversations with each other, which seems to be an artifact of online communication that was coded either as collaboration or knowledge construction in this dissertation study.

These suggestions for adding scaffolds to LMS are meant as a starting point for design work aimed at direct support of collaboration and knowledge construction. Since LMS is broadly applied to several different contexts and disciplines, scaffolds may have to be specifically designed for these different audiences that the user can then self-identify as (e.g., humanities, social science, or natural science). Future research will need to explore different applications of scaffolding within LMS in order to make a reasoned argument about which scaffolds work best for which audience within these systems.

5.2.2 Some Suggestions for Improving LMS Design

In the online surveys and focus group interviews in this study, students were asked about their problems and frustrations with the LMS technology as well as their recommendations for improvements. Based on their input, I list the students' general problem or issue and then my suggested modifications that could improve students' overall experience with the LMS as well as help minimize the more routine management tasks common in course-related projects. These improvements could allow students to reduce their cognitive load and instead focus and deeply engage with the concepts central to their groups' objective (Quintana et al. 2004). These suggestions include:

1. **Problem:** Students complained that they accidentally overwrote each other's drafts while collaboratively writing and editing their mock NIH grant proposals. **Suggested Modification:** Add a simple "versioning" module to the Resources tool and any attachments widgets so that collaborative groups can easily update versions of common documents. Group members will also then be able to easily view changes from previous versions and revert to those previous iterations, if necessary.
2. **Problem:** Students complained that there was not enough flexibility in the provided toolset, they could not control the look and feel of the page view, and they could not view the provided tools while also using external web resources, such as a virtual white board.
   Suggested Modification: Allow students to control the look and feel of every "page" within a LMS project site in order for students to customize the LMS tools to their particular work pattern (e.g., arrive at a better task-technology fit (Jarvenpaa, 1989)). For example, Group PS-D could have turned the Chat tool into a double-column view with the second column activated as an iframe that could be directed to a picture, document, or external website. Such functionality would be a precursor to true "mash-up" technology within LMS (Severance, Hardin, & Whyte, 2008).
3. **Problem:** Students complained that they could not readily tell which group members were online within the entire LMS and therefore available to chat synchronously.
   Suggested Modification: Allow students to instantly message each other within

the LMS or send an internal system invitation to other members of their project site who are also online. This would better match students' pre-established habits for using online systems that allow synchronous communication (e.g., Facebook) (Lee, Miller, & Newnham, 2009).

4. **Problem:** Students are given blank content management tools (e.g. Resources) without scaffolds or hints of how to organize their materials.
   Suggested Modification: Automatically add common folders to the Resources tool such as "Research Articles," "Drafts," and "Online Examples." These suggested folders could help scaffold students' process management (Quintana et al., 2004) and also give students an initial idea of what kinds of materials are needed in order to substantiate and legitimize their claims in their project.
5. **Problem:** Students are given a blank slate in the Wiki tool without any scaffolds or hints of how to use this powerful collaborative document editing tool. This is part of the reason why the one student group who used the Wiki tool in this dissertation study ultimately abandoned it.
   Suggested Modification: Allow students to choose from a selection of templates in the Wiki tool depending on the type of document they want to start with. Some possible templates might include brainstorming, a summation of research findings, a checklist of tasks related to the group project, main arguments for the final paper, etc. Additionally, the wiki tool could also include reflective prompts to help students monitor and plan their learning (Davis & Linn, 2000; Ge & Land, 2004).
6. **Problem:** Students may not know which external websites / tools might be beneficial for their group project.
   Suggested Modification: The LMS could prompt students for suggested websites to help with basic group management tasks (e.g., Doodle (www.doodle.com) for arranging face-to-face meetings, group calendar websites for shared deadlines, etc.). These suggestions could be categorized by functionality that the students indicate that they are interested in and also accept suggested new websites by students in other project sites. The LMS project site could thus become a specific type of portal that helps students organize their various organizational tasks and also link to the myriad of different tools and resources available through the Internet (Katz, 2002).

These suggested modifications are not meant to be exhaustive, but rather to illustrate the kinds of improvements that can help students manage the more basic functions of group work and then focus on the collaboration necessary to construct new knowledge. Future research could explore if and how these improvements facilitate collaboration and knowledge construction and whether these improvements result in less need for face-to-face communication once users can accomplish more within the LMS.

5.2.3 Student-Oriented Focus in LMS-Related Literature

One of the implications of this dissertation study is a demonstration that interaction, collaboration, and knowledge construction have the potential to occur within LMS in situations that do not include instructor mediation. Studies investigating LMS, reviewed in Chapter 2 of this dissertation, have thus far focused on instructors' use of LMS and students' use in course-oriented sites where the instructor retained control and acted as a mediator or coach for interactive activities online. During the term this dissertation study was conducted, nearly 3,300 project sites (approximately 60% by students) were created within the campus LMS, representing the broad-based phenomenon of non-course related uses of this technology. The successful use and positive response of students in a relatively unstructured approach to using LMS technology in this dissertation study will hopefully spark new interest in not only researching project-oriented uses of LMS, but also new technologies and designs with student-created, student-managed, and student-directed work in mind. Furthermore, this area of research could serve to inform course-based uses of LMS and apply the kinds of collaborative, student-oriented, and project-based pedagogies advocated by several researchers investigating LMS (e.g., Papastergiou, 2006; Watson & Watson, 2007).

5.2.4 Applicability Beyond This Case Study

While case studies provide rich, descriptive data about particular uses and cases, it is sometimes difficult to then apply the findings of these studies to more generalized situations or to more tightly controlled research studies (Merriam, 1998; Yin, 2003). However, I believe that by allowing students to direct their own use of the LMS within the context of their course-related project, the findings from this dissertation study are easily applied to other biology and science-based courses that utilize student projects and could also employ LMS as a technology to facilitate group interaction. It is noteworthy that 66% (82 students) of a large biology course opted to use LMS project sites with very little incentive and virtually all of them found their use of the technology useful for their group project and indicated that they would use the LMS again for future projects. These findings demonstrate the value added by LMS project sites on top of the documented value for course sites and the relative ease of establishing project sites within the same overall system (Lonn & Teasley, 2009). Furthermore, as discussed in Chapter 2 of this dissertation, there is collaborative work being conducted not only in "hard" sciences, but also in social sciences and, to some extent, in the humanities as well. This study could be easily modified to explore collaboration between disciplines that would extend the "circle of researchers" interested in how LMS can facilitate interaction, collaboration, and knowledge construction (e.g., Hafernik et al., 1997).

5.3 Limitations of This Study

5.3.1 The Researcher's Lack of Expertise in MCDB

Although I have taken a few higher education courses in biology, I am by no means an expert in the area of molecular, cellular, or developmental biology. Thus, many of the terms, concepts, and procedures discussed by students are foreign to me, and I am unable to make a decision as to whether students' opinions are correct according to current biological theory. However, while some may view this lack of expertise as a limitation, I personally view it as a strength because I am not encumbered by the minutia of students' comments and can concentrate on the overall scope of the message. In terms of my coding of social construction of knowledge, it is irrelevant whether students' collective understanding is correct. It is more important that the students were able to use the knowledge held by individual group members in order to build a new, collective understanding of biological concepts and procedures.

5.3.2 Students' Collocation and Lack of Data from Students' Use of Non-LMS Technologies

As previously discussed in this chapter, students in this study lived in close proximity to one another, thus allowing for easier arrangement of face-to-face meetings. The high frequency of these meetings increases the likelihood that significant collaboration and knowledge construction took place outside of the LMS project sites.

Furthermore, the results from the online surveys reveal that students actively used non-LMS technologies such as email, cellular phones, and instant messaging programs in order to communicate with one another. The lack of information from all of these potential data sources significantly limits the ability to fully describe students' collaborative process, despite the fact that such interaction was beyond the scope of this study. Future research could possibly ask students to include the investigators in their face-to-face sessions and in their email communication. Alternatively, students could be asked to forgo such technologies in favor of greater dependence on the LMS for communication between group members. Finally, a future study might investigate students' use of LMS project sites on a commuter campus or in distance education settings where students are not co-located and have more difficulty in arranging face-to-face meetings. Such research could build on the existing LMS-related literature that is situated in distance education (e.g., Bradford, Porciello, Balkon, & Backus, 2006-2007; Falvo & Johnson, 2007; Topper, 2003).

5.3.3 Student Familiarity With and Use of LMS Project Sites

Although nearly every student at the university where this study was situated has been enrolled in at least one course using the LMS, not every student was familiar with the project site functionality of the system. While I attempted to negate this unfamiliarity by offering a training session and subsequently emailing the training handout to all students in the course, not every student who eventually used a project site attended (8 out of 21 groups who used the LMS were represented at the training session). Although there did not appear to be any major difference in LMS used based on at my training sessions or use of my training materials, I would suggest that future studies of student use of project sites allot a brief amount of time during the course lecture to review how to create and set up project sites as well as to distribute materials of suggested use of the technology relevant to the students' project.

Students could not only elect whether to use the LMS, they could also choose which tools to activate and how to use them. While I argue that this flexibility is a positive design element of the LMS and presents a more realistic view of how students use the technology, it also demonstrates a lack of variable control within the study. For example, group PS-T did not turn on any interactive tools, while group PS-E turned on three interactive tools (Announcements, Chat, and Discussion) and experimented with all of them (8 total messages). If students had been directly instructed to activate both content sharing and interactive tools, they may have had more opportunities to explore the LMS as a way to interact with each other online. Future research could also explore whether student control or institutional control of tool activation leads to increased levels of interaction, collaboration, and knowledge construction.

5.3.4 Unequal Participation Rates in Data Sources

There were a variety of data sources used in this study, including peer-to-peer message units, LMS event logs, online surveys, and focus group interviews. However, not all of the students who used the LMS project sites participated in the online surveys and focus group interviews, thus creating gaps in information about how and why students used the technology. While the average participation rate for the online surveys was 42.5%, a rate higher than the typical response rates for this type of online survey (Cook et al., 2000; Kaplowitz et al., 2004), a majority of students in the course did not respond to the survey. Furthermore, only eight (38%) of the twenty-one student groups who used the LMS participated in the focus group interviews. Therefore, while the event log files and peer-to-peer message units provide quite a bit of information about how students used their LMS project sites, the students who did not participate in the online surveys and focus group interviews represent potential missing pieces of information that might have better described how students used LMS to interact, collaborate, and construct knowledge.

5.4 Suggestions for Future Research

As already indicated in this chapter, there are several potential areas for future research based on the findings from this dissertation study. One natural extension of the work described in this study is to see if students in a different course, discipline, or type of university use LMS to complete their course-related project. Differences in the LMS, course context, university setting, group composition, and other factors could all significantly vary the findings in this type of study and might further explain how LMS can successfully facilitate students' collaborative knowledge construction. Furthermore, a researcher might be interested to see how students' peer interaction changes when an instructor is invited to observe or even moderate the online discourse within a LMS project site. Discovering how an instructor can act as a guide while students retain the overall control of the LMS site could be an interesting line of research.

Throughout this dissertation study, I have purposefully tried to link LMS, a type of technology designed to appeal to many different kinds of instructional situations, disciplines, and circumstances, to CSCL environments, which are often narrowly designed with a particular instructor, discipline, or situation in mind for implementation (e.g., The Math Forum (Renninger & Shumar, 2002; 2004)). The defined purpose of LMS is to facilitate teaching and learning by utilizing the power of online technologies and supporting instructors' and students' use of those technologies in one easy-to-use space. The research on these systems is similar to Rick and Guzdial's (2006) description of "application mode" research in which researchers apply existing learning theories to solve an important learning problem, even though the solution may be very concrete and impossible to abstract to other situations or circumstances. By directly applying the theories and literature from the CSCL community, my intention was to show that LMS is one possible venue for application mode research and has the potential to support collaborative learning. There are, however, additional areas of research that could inform improved design and study of LMS including computer-supported collaborative work (CSCW), human-computer interaction (HCI), and even group dynamics literature.

Another avenue of potential future research is further exploration of the multitude of factors that influence whether students' online basic interaction can be further characterized as collaboration and knowledge construction. Within this dissertation study, there were several factors identified that were ultimately dismissed because of a lack of correlation with the number of collaboration or knowledge construction peer-to-peer message units including: group size, distribution of content sharing and interactive log events, distribution of interactive activity within the LMS project sites, students' perceptions of how evenly distributed the work was within their group, computer expertise, prior group experience, and high versus low levels of LMS use. Future research could uncover additional factors as well as apply different methodologies, such as those from group dynamics literature, in order to investigate the factors listed above.

Finally, an area of potential future research is identifying the best types of scaffolds to support collaboration and knowledge construction within LMS. How these scaffolds should be designed and implemented is an important area to investigate in order for LMS to successfully support students' peer interaction instead of leaving collaboration and knowledge construction to happen within this technology haphazardly, if at all. Both researchers and designers must work together in this area of research in order for the adoption of scaffolding within LMS to be successful. The rapid innovation possible in open source LMS approaches such as Moodle or Sakai may be a logical place to begin these kinds of explorations. Furthermore, additional scaffolds will be needed to guide students' peer interaction in existing tools provided within LMS, but also to guide the selection of external tools for collaboration and knowledge construction as these systems mature and provide more opportunities to "mash-up" or combine web technologies, widgets, and information all in one common space (Severance, et al., 2008). It is intended that the few scaffolds I have suggested above will spark new ideas about scaffolding within LMS and that designers will consider adopting scaffolds and strategies that have successfully facilitated collaboration and knowledge construction in other computer-supported collaborative learning environments. When such design considerations are a routine exercise in building new functionality within LMS, then learning *and* management may be equally supported within these systems.

5.5 Conclusion

This study demonstrated that students successfully used LMS project sites to facilitate their groups' peer interaction and, to some extent, collaboration within the context of a course-related group project. However, there was very little evidence of students' knowledge construction within the LMS technology. Several factors were identified that may have influenced whether students' basic interaction within LMS could be further distinguished as collaboration and knowledge construction, including the technological limits of the LMS as well as the ease of students to meet in face-to-face sessions to discuss their course-related project. Many instances of students' construction of new understandings thus likely occurred in face-to-face meetings and were thus not evidenced within the LMS. However, the few peer interactions coded as knowledge construction within the LMS indicate that students took significantly more words to express their thoughts and opinions than basic interaction and collaboration. Overall, the students found the LMS technology useful for their collaboration throughout the semester and indicated that they would use the technology again for future course-related projects and assignments.

In future research, the applicability of technological scaffolds within LMS could be explored in order to better support student collaboration and knowledge construction. Such scaffolds should draw on previous literature, particularly from CSCL environments that have demonstrated that students are able to learn from one another using online technologies (e.g., Knowledge Forum (Scardamalia & Bereiter, 1991), CoVis (Pea et al., 1994), GLOBE (Finarelli, 1998)).

As with any study investigating technology, it is not as important that students used LMS project sites, but *how* they used them. Within the twenty-one groups who used the LMS in order to complete their course-related project, there was a wide range of use, from groups who only placed a few documents in the Resources tool to groups who used a variety of interactive tools to collaborate and learn about important biological concepts from one another. Furthermore, this study demonstrated that students within their own LMS sites used the interactive tools to discuss and collaborate about the documents stored in the Resources tool, breaking down the dichotomy of materials sharing vs. interactive teaching and learning witnessed in course-oriented uses of LMS technology (e.g., Lonn & Teasley, 2009). This study also builds on LMS-related literature discussing student learning and knowledge construction (e.g., G. Morgan, 2003; Oliver, 2001; Watson & Watson, 2007; West et al., 2007) by directly investigating if and how students interacted and learned from one another using LMS without direct instructor support or guidance.

> "The combination of learning principles and (LMS) tools … results in a learning environment that is greater than simply the sum of its parts. This potential, often strived for but much less often realized, continues to bring faculty and students to the (LMS) with an excitement and determination that rests on the hope of deeper, more meaningful, engaged learning" (Carmean & Haefner, 2002, pp. 34)

This study demonstrates that future research is necessary to explore the various ways that LMS can facilitate student interaction, collaboration, and knowledge construction, both with instructor mediation and guidance and without. As expressed in the quote above, LMS are complex, multifaceted systems that require continued design improvements as well as attention from instructors, instructional designers, and researchers in order to achieve their potential as a technological facilitator for student learning.

APPENDIX A: BEGINNING-OF-TERM ONLINE SURVEY INSTRUMENT

CTools Project Sites Survey 1

This survey asks questions about the CTools project site that you are using or will potentially use for your NIH Grant Proposal assignment.

Please do NOT include your thoughts about CTools official course sites (sites that you are using/used as part of a class that you were/are enrolled in or auditing).

1. Rate your overall expertise with computers:

❍ Novice
❍ Intermediate
❍ Advanced

2. Please rate your expertise with the following technologies:

	Have Not Used	Novice	Intermediate	Advanced
Instant messaging	❍	❍	❍	❍
Sending / receiving text messages via cell phone	❍	❍	❍	❍
Online scheduling / calendaring	❍	❍	❍	❍
Library online search tools for research projects / papers	❍	❍	❍	❍
Peer networking websites (e.g. Facebook, MySpace, LinkedIn)	❍	❍	❍	❍
Downloading / listening to digital music	❍	❍	❍	❍
Downloading / listening to podcasts	❍	❍	❍	❍
Store / view digital pictures online	❍	❍	❍	❍
Watching digital videos online	❍	❍	❍	❍
Creating digital videos	❍	❍	❍	❍

3. For how many university courses have you previously participated in group assignments / projects?

None	1 other course	2-4 courses	5-7 courses	8-10 courses	11 or more courses
❍	❍	❍	❍	❍	❍

4. Please rate your agreement with the following statements:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	N/A
I enjoy working with other students on course assignments / projects	❍	❍	❍	❍	❍	❍
I think that work is usually distributed fairly in group assignments / projects	❍	❍	❍	❍	❍	❍
I typically end up doing all of the work in group assignments / projects	❍	❍	❍	❍	❍	❍

5. Briefly state the planned topic for your NIH grant proposal.

6. How many students are in your NIH grant proposal group, including yourself?

1	2	3	4	5	6	I have not decided yet
❍	❍	❍	❍	❍	❍	❍

7. Did you attend the CTools project site training session on Monday, January 14th?

❍ Yes

❍ No

8. Did you attend the CTools project site training session on Friday, January 18th?

- ❍ Yes
- ❍ No

9. Please rate the following:

	Very Low	Low	Medium	High	Very High
My **knowledge** about using CTools project sites.	❍	❍	❍	❍	❍
My **experience** about using CTools project sites.	❍	❍	❍	❍	❍
My **confidence** about using CTools project sites.	❍	❍	❍	❍	❍

10. How many different CTools project sites did you use during Fall term 2007?

- ❍ None
- ❍ 1-2 project sites
- ❍ 3-5 project sites
- ❍ 6-10 project sites
- ❍ More than 10 project sites

11. How often do you plan to visit your project site?

- ❍ A few times during the semester
- ❍ A few times a month
- ❍ Once a week
- ❍ A few times a week
- ❍ Daily (once or more)

*For questions 12 & 13, the word **collaborate** will be used to describe activities in which you work with, communicate, share materials with, or otherwise participate with others.*

12. Please rate how **useful** you think the following tools will be to help you **collaborate** with your fellow group members.

	Not Useful At All	Somewhat Not Useful	Neutral	Somewhat Useful	Very Useful	Not Sure or Have Not Used Before
Announcements	❍	❍	❍	❍	❍	❍
Chat Room	❍	❍	❍	❍	❍	❍
Discussion	❍	❍	❍	❍	❍	❍
Email Archive	❍	❍	❍	❍	❍	❍
Forums	❍	❍	❍	❍	❍	❍
Messages	❍	❍	❍	❍	❍	❍
News (RSS Feeds)	❍	❍	❍	❍	❍	❍
Podcasts	❍	❍	❍	❍	❍	❍
Resources	❍	❍	❍	❍	❍	❍
Schedule	❍	❍	❍	❍	❍	❍
Web Content	❍	❍	❍	❍	❍	❍
Wiki	❍	❍	❍	❍	❍	❍

13. Which tool(s) do you think will be the most useful for collaboration with other project site participants? Why?

14. What is your year in your program?

❍ First-year undergraduate
❍ Sophomore
❍ Junior
❍ Senior (4 or more years)
❍ Masters student
❍ Doctoral student

15. What school or college are you primarily affiliated with? Please select one.

- ❍ Business School
- ❍ College of Architecture and Urban Planning
- ❍ College of Engineering
- ❍ College of Pharmacy
- ❍ Division of Kinesiology
- ❍ Law School
- ❍ LS&A Humanities (American Culture, Asian Languages, CAAS, Classical Studies, Comp. Lit., ELI, English, Film & Video, German, History of Art, Judaic Studies, Linguistics, Near Eastern Studies, Philosophy, Residential College, Romance Languages, Slavic Languages)
- ❍ LS&A Natural Science (Applied Physics, Astronomy, Chemistry, EEB, Geological Sciences, Mathematics, MCDB, Physics, Program in the Environment, Statistics)
- ❍ LS&A Social Science (Anthropology, Communication Studies, Economics, History, International Institute, Organizational Studies, Political Science, Psychology, Sociology, Women's Studies)
- ❍ LS&A Undeclared
- ❍ Medical School
- ❍ School of Art and Design
- ❍ School of Dentistry
- ❍ School of Education
- ❍ School of Information
- ❍ School of Music
- ❍ School of Natural Resources and Environment
- ❍ School of Nursing
- ❍ School of Public Health
- ❍ School of Public Policy
- ❍ School of Social Work

16. If you are a Biology major, what is your area of concentration? (e.g. Neuroscience) No abbreviations please!

17. Are you "pre-med" (applying or plan to apply to medical school)?

- Yes
- No

18. I currently live:

- In Central Campus housing
- In North Campus housing
- Within walking distance of Central campus
- Within walking distance of North or Medical campus
- 1-10 miles from any Michigan campus
- 11-20 miles from any Michigan campus
- More than 20 miles from any Michigan campus

19. Are you:

- Female
- Male

20. Do you have any other comments about CTools project sites?

To finish the survey, click the "Submit" button below

Submit

APPENDIX B: END-OF-TERM ONLINE SURVEY INSTRUMENT

CTools Project Sites Survey 2

This survey asks questions about the CTools project site that you used for your NIH Grant Proposal assignment.

Please do NOT include your thoughts about CTools official course sites (sites that you are using/used as part of a class that you were/are enrolled in or auditing).

1. Rate your overall expertise with computers:

- ❍ Novice
- ❍ Intermediate
- ❍ Advanced

2. Please rate your expertise with the following technologies:

	Have Not Used	Novice	Intermediate	Advanced
Instant messaging	❍	❍	❍	❍
Sending / receiving text messages via cell phone	❍	❍	❍	❍
Online scheduling / calendaring	❍	❍	❍	❍
Library online search tools for research projects / papers	❍	❍	❍	❍
Peer networking websites (e.g. Facebook, MySpace, LinkedIn)	❍	❍	❍	❍
Downloading / listening to digital music	❍	❍	❍	❍
Downloading / listening to podcasts	❍	❍	❍	❍
Store / view digital pictures online	❍	❍	❍	❍
Watching digital videos online	❍	❍	❍	❍
Creating digital videos	❍	❍	❍	❍

3. Briefly state the topic for your NIH grant proposal.

4. How often did your NIH grant proposal group meet **face-to-face**?

- ❍ My group never met face-to-face
- ❍ A few times a month
- ❍ Once a week
- ❍ A few times a week
- ❍ Daily (once or more)

5. What did you and your group members talk about during your face-to-face meetings?

6. Why did your group meet face-to-face instead of having these same discussions online?

Your CTools Project Site

7. How often did you visit your CTools project site?

- ❍ My group did not have a CTools project site for the NIH grant proposal project
- ❍ A few times during the semester
- ❍ A few times a month
- ❍ Once a week
- ❍ A few times a week
- ❍ Daily (once or more)

8. Please rate how **useful** you found the following activities in your CTools project site:

	Not Useful At All	Somewhat Not Useful	Neutral	Somewhat Useful	Very Useful	Did Not Use
Posting questions to other group members	❍	❍	❍	❍	❍	❍
Commenting on other group members' work	❍	❍	❍	❍	❍	❍
Posting documents or other materials online	❍	❍	❍	❍	❍	❍
Sending messages / announcements / notifications to other group members	❍	❍	❍	❍	❍	❍
Collaboratively writing a document with group members online	❍	❍	❍	❍	❍	❍
Linking to a website outside of the CTools environment	❍	❍	❍	❍	❍	❍
Linking to a RSS news feed	❍	❍	❍	❍	❍	❍
Answering questions from other group members	❍	❍	❍	❍	❍	❍
Receiving comments on my work from other group members	❍	❍	❍	❍	❍	❍
Accessing documents or other materials online that other group members have posted	❍	❍	❍	❍	❍	❍
Receiving messages / announcements / notifications from other group members	❍	❍	❍	❍	❍	❍

9. Please rate your agreement with the statements below:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Using a CTools project site helped me communicate with my other group members.	❍	❍	❍	❍	❍
Using a CTools project site helped me learn from my other group members	❍	❍	❍	❍	❍
My NIH grant proposal assignment was more successful because my group used a CTools project site	❍	❍	❍	❍	❍
My NIH grant proposal assignment received a higher grade because my group used a CTools project site	❍	❍	❍	❍	❍

Collaboration

*For questions 10-12, the word **collaborate** will be used to describe activities in which you worked with, communicated, shared materials with, or otherwise participated with your group members about your NIH grant proposal assignment.*

10. Please rate how **useful** the following tools were to help you **collaborate** with your fellow group members:

	Not Useful At All	Somewhat Not Useful	Neutral	Somewhat Useful	Very Useful	Not Sure or Have Not Used Before
Announcements	❍	❍	❍	❍	❍	❍
Chat Room	❍	❍	❍	❍	❍	❍
Discussion	❍	❍	❍	❍	❍	❍
Email Archive	❍	❍	❍	❍	❍	❍
Forums	❍	❍	❍	❍	❍	❍
Messages	❍	❍	❍	❍	❍	❍
News (RSS Feeds)	❍	❍	❍	❍	❍	❍
Podcasts	❍	❍	❍	❍	❍	❍
Resources	❍	❍	❍	❍	❍	❍
Schedule	❍	❍	❍	❍	❍	❍
Web Content	❍	❍	❍	❍	❍	❍
Wiki	❍	❍	❍	❍	❍	❍

11. Which tool(s) do you think was the most useful for collaboration with other group members? Why?

12. How do you think existing tools within CTools could be improved to better facilitate collaboration?

Non-CTools Technologies

13. What other tools / methods did you use to collaborate with your group members **outside of the CTools environment?** (check all that apply)

- ❑ Email
- ❑ Face-to-Face conversation / meetings
- ❑ Facebook / MySpace / LinkedIn / or other peer connection website
- ❑ File sharing system (e.g., local server, mFile, etc.)
- ❑ Google Documents
- ❑ Instant messaging
- ❑ Non-CTools blog
- ❑ Non-CTools wiki
- ❑ Telephone / cell phone (voice)
- ❑ SMS text messaging (e.g., texting)
- ❑ Other tool / method (please specify):

14. If you used collaborative technologies outside of the CTools environment, please briefly explain:

- Why you chose to use those technologies AND
- How you used the technologies to collaborate with your group members

15. Were these non-CTools technologies helpful for collaborating about your grant proposal assignment? Why?

Additional Information About Your Grant Proposal Group

16. What grade did you receive for your NIH Grant Proposal Assignment?
If you submitted for a re-grade, please enter your first grade received.

points out of 100 possible points

If you submitted your assignment for a re-grade, please enter the revised grade below:

points out of 100 possible points (re-graded)

17. Please rate your agreement with the statements below:

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Overall, my group worked well together to complete the NIH grant proposal assignment	❍	❍	❍	❍	❍
The work for the NIH grant proposal assignment was distributed evenly between group members	❍	❍	❍	❍	❍

18. Please answer the following statements using numerical values between 0 and 100%:

Overall, I feel that **my group members** gave % effort while working on the NIH grant proposal assignment

Overall, I feel that **I** gave % effort while working on the NIH grant proposal assignment

19. Please briefly explain your answer about the amount of effort you and your group members provided while working on the NIH grant proposal assignment:

Your comments will remain confidential

Your Overall Opinions About CTools Project Sites

*For the remaining questions, please think about **ALL** of the CTools project sites that you are using or have used in the past.*

20. Creating a CTools project site is

Difficult 1	2	3	4	Easy 5
❍	❍	❍	❍	❍

21. Please rate the following:

	Very Low	Low	Medium	High	Very High
My **knowledge** about using CTools project sites.	❍	❍	❍	❍	❍
My **experience** about using CTools project sites.	❍	❍	❍	❍	❍
My **confidence** about using CTools project sites.	❍	❍	❍	❍	❍

22. Please rate your agreement with the statements below:
Using CTools project sites is valuable for...

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Improving my learning	❍	❍	❍	❍	❍
Saving me time (efficiency)	❍	❍	❍	❍	❍
Accessing material any time, from any location (convenience)	❍	❍	❍	❍	❍
Managing my project-related activities	❍	❍	❍	❍	❍
Improving my communication with other project site participants	❍	❍	❍	❍	❍
Improving other project site participants' communication with me	❍	❍	❍	❍	❍

23. Which of the following benefits from using CTools project sites is the **most valuable** to you? Please select one.

- ❍ Improving my learning
- ❍ Saving me time (efficiency)
- ❍ Accessing material any time, from any location (convenience)
- ❍ Managing my project-related activities
- ❍ Improving my communication with other project site participants
- ❍ Improving other project site participants' communication with me
- ❍ No benefits
- ❍ Other (please specify):

24. What do you wish you could do with CTools project sites that you currently are not able to do?

25. Please rate the **likelihood** of the following statements:

	Very Unlikely	Somewhat Unlikely	Neutral	Somewhat Likely	Very Likely
I will use CTools project sites for future course-related projects/assignments.	❍	❍	❍	❍	❍
I will use CTools project sites in the future for non course-related activities.	❍	❍	❍	❍	❍
I will recommend CTools project sites to other students that I know.	❍	❍	❍	❍	❍

26. Do you have any other comments about CTools project sites?

To finish the survey, click the "Submit" button below

Submit

APPENDIX C: STUDENT FOCUS GROUP INTERVIEW PROTOCOL

I would like to talk to you today about your use of CTools project sites for your NIH grant proposal assignment. I'll give each of you a chance to answer each question. If you don't want to answer a question, that's okay. If someone says something that you'd like to comment on or have a question about, please wait until they are done talking first.

Introduction

1. What was the topic of your NIH grant proposal assignment?
    a. How did you arrive at this topic?
    b. Was it one person's idea? Was it a combination of different ideas?
    c. How did the topic change throughout the proposal process?

Genesis of CTools Project Site

2. Let's start talking about your use of the CTools project site.
    a. Who created the site?
    b. How did you first start to use it?
        i. Why?
3. Did your group discuss how to use the site?
    a. How did you decide how members would interact on the site?
        i. For example, how did you figure out how to organize the resources area?
    b. Did specific group members have specific tasks on the site?
        i. What tasks?
        ii. Why?

Tool Use

4. According to the CTools logs, you used the ______ tool the most on your site. Generally, how did you use this tool? Why?
    a. What did you upload/download/talk about with this tool?
        i. Was a particular type of file / topic easier to work with / discuss than others? Why?
    b. Did different group members use this tool differently? How? Why?
    c. What are some of the features about this tool that *help* you to work together as a group?
        i. Can you give me an example?
    d. What are some of the features about this tool that make it *harder* to work together as a group?
        i. Can you give me an example?

    e. (if applicable) I noticed that you all used this tool more at the _________ of the term and less at the __________ of the term. Can you tell me why?
        i. Did you use a different CTools project site tool instead?
        ii. Did you use a tool outside of CTools instead?

5. *(for each tool)*
   The CTools logs also indicated that you used the ______ tool on your site. Generally, how did you use this tool? Why?
    a. What did you upload/download/talk about with this tool?
        i. Was a particular type of file / topic easier to work with / discuss than others? Why?
    b. Did different group members use this tool differently? How? Why?
    c. What are some of the features about this tool that *help* you to work together as a group?
        i. Can you give me an example?
    d. What are some of the features about this tool that make it *harder* to work together as a group?
        i. Can you give me an example?
    e. (if applicable) I noticed that you all used this tool more at the _________ of the term and less at the __________ of the term. Can you tell me why?
        i. Did you use a different CTools project site tool instead? Why?
        ii. Did you use a tool outside of CTools instead? Why?

Group Interaction, Collaboration, and Knowledge Construction

6. We've talked a lot about how you've used the different tools and how you all used CTools project sites. Overall, do you think you learned from other project site members through your use of the project site?
    a. What did you learn?
    b. How do you think you learned from them?
    c. Is there an example where you learned something about your NIH grant proposal topic from another group member via a CTools project site tool?
        i. What happened?
        ii. How did this help you complete your assignment?
        iii. What could have made this process easier?

7. Did your group meet face-to-face?
    a. When? How often? Where?
    b. Did your face-to-face interaction differ from how you communicated with each other online? How? Why?
    c. Was there a time when it was easier to meet face-to-face versus online? Or vice-versa?
        i. Who made that decision? Why?
        ii. Do you feel that you were able to get more/less accomplished than meeting face-to-face/online? Why?

8. Did your group use any non-CTools technologies to communicate or collaborate with each other?
    a. Which ones?
    b. Why did you use these technologies?
        i. Why didn't you conduct this kind of communication / collaboration within your CTools project site?
        ii. Do you think CTools or other technology could ever replace this kind of interaction? Why/not?
    c. Is there a tool that could be added or changed to better facilitate this kind of communication / collaboration?

9. Overall, how do you think your group worked together?
    a. Do you think CTools project sites make it easier or harder for group members to work together?
        i. Why?
        ii. Can you give me an example?

Future Use of CTools Project Sites

10. How would you compare your experience with CTools project sites to your overall experience with CTools course sites?
    a. What is the difference between how instructors use their course sites and how you use project sites?
    b. Do you think instructors should change their CTools practices given your experience on project sites?

Why?

11. Do you think that you would use CTools project sites again? Why / why not?
    a. For what purpose? Why?

12. Is there anything else you'd like to say or discuss about project sites?

Thank you for talking with me today.

APPENDIX D: INSTRUCTOR BEGINNING-OF-TERM INTERVIEW PROTOCOL

I would like to talk to you today about your course, the NIH grant proposal assignment, and your use of CTools for your courses. If you don't want to answer a question, that's okay.

Introduction

1. Can you tell me a little bit about your educational experience?
    a. How and when did you arrive at your position here at Michigan?
    b. What courses do you typically teach over the academic year?

2. Can you briefly describe this course?
    a. How many times have you taught this course?
    b. What are students expected to take away from this course?
    c. What topics do you lecture about?
    d. What do students do during their lab sessions? Why?
    e. Other than the NIH grant proposal, what are students' assignments and exams for the course?
        i. What are they expected to learn / know from these assignments?
    f. Is there anything else you'd like to tell me about this course?

NIH Grant Proposal Assignment

3. Let's talk specifically about the NIH grant proposal assignment. Please briefly describe what this assignment entails.
    a. Are their different steps or drafts that you review?
        i. Is there a rubric or guide for students?
    b. Why did you create this assignment?
    c. What are students expected to learn from this assignment?
    d. Have students met your expectations in past years? How / why not?
        i. Can you give me an example of a successful and unsuccessful assignment?
    e. What kinds of announcements or advice do you give students about the assignment during lecture?
        i. Can you give me an example or two?

4. You allow students to complete the assignment by themselves or in groups of 2-6 students. Why is this so?
    a. Do you think that students who work together to complete the assignment are more successful than those who work alone? Why?

        i. Can you give me an example?
        ii. If you do think that students are more successful if they work in groups, then why do you provide the option for students to work alone?
    b. Do you think that smaller groups of 2-4 students work better together than larger groups of 5-6 students? Why?

5. Do you meet with students about their NIH grant proposal assignment individually and/or in groups during the semester?
    a. What do students usually ask about during these meetings?
    b. What advice do you offer?
    c. Have you found that students who visit with you during the semester are more/less successful on their overall assignment?
        i. Why do you think this is so?

CTools and Technology Use

6. Let's talk a bit about your use of CTools and other technologies for this course.
    a. Do you have a CTools course site for this course? When did you create the site? When did you publish it for student access?
    b. What tools do you use on the site?
        i. How do you use them?
            1. Can you give me an example (e.g., why would you send an announcement, what kind of file do you post to resources, etc.)
    c. Have students ever commented on your use of CTools?
        i. What have they said?
        ii. How have you incorporated their suggestions into your use of CTools?
    d. Is there something that you would like to do with CTools that you currently cannot or don't know how to do?
        i. Can you give me an example?
    e. Do you have any other comments about CTools course sites?

7. Do you use any other kinds of technology for your course? Which ones?
    a. Why do you use these technologies?
    b. Have students commented on your use of these technologies?
        i. What have they said?
    c. Do you have any other comments about your use of technology for your course?

8. My research is interested in how students use CTools project sites.
    a. Have you ever used a CTools project site?
        i. What was the context?
        ii. What tools did you use? How did you use them?

b. Do you feel that your interaction with other site participants was successful? Why?
c. Was there anything about the various tools or overall design that made it difficult to interact with other site participants?
    i. Can you give me an example?
    ii. How do you think the design could be improved?
d. Do you have any other comments about CTools project sites?

9. Do you have any other comments about your course, NIH grant proposal assignment, or anything else?

Thank you for talking with me today.

APPENDIX E: INSTRUCTOR END-OF-TERM INTERVIEW PROTOCOL

I would like to talk to you today about the NIH grant proposal assignment and your students' use of CTools project sites. If you don't want to answer a question, that's okay.

Introduction

1. Overall, do you feel that students met your expectations for the NIH grant proposal assignment this year? Why / why not?
    a. Can you give me an example of a successful and unsuccessful assignment from this years' course?

Group Interaction & Size

2. Did you meet with students about their NIH grant proposal assignment individually and/or in groups during the semester?
    a. What did students typically ask about during these meetings?
    b. What advice did you offer?
    c. Did you found that students who visited with you during the semester were more/less successful on their overall assignment?
        i. Why do you think this is so?
    d. As the semester progressed, did you notice any changes in group dynamics? For example, did a student group have difficulty working together at the beginning of the semester but later was able to collaborate well with each other?
        i. Can you give me an example or two?
        ii. In your opinion, what helps determine whether a group will work well together?

3. At the beginning of the semester, we talked about groups versus individuals who completed the term project.
    a. For this years' course, do you think that students who worked together to complete the assignment were more successful than those who worked alone? Why?
        i. Can you give me an example?
    b. For this years' course, do you think that smaller groups of 2-4 students worked better together than larger groups of 5-6 students? Why?
    c. Has your experience with various sizes of groups this semester impacted you approach to groups for this assignment in the future?
        i. Will you encourage or require groups of a certain size or composition? Why / why not?

CTools Course Site & Other Technology Use

4. At the beginning of the semester, we talked a bit about your planned use of your CTools course site.
    a. What tools did you use on the site?
        i. How did you use them?
            1. Can you give me an example (e.g., why would you send an announcement, what kind of file do you post to resources, etc.)
    b. Did students comment on your use of CTools?
        i. What did they say?
        ii. How do you plan to incorporate their suggestions into your use of CTools in the future?
    c. Is there something that you would like to do with CTools that you were not able to do this semester?
        i. Can you give me an example?
    d. Do you have any other comments about CTools course sites?

5. I noticed that in their project sites, many students used ______ tool in _________ way.
    a. (for similar activity) Do you think that students copied your use of ____tool in the course site for their project site use? Why?
        i. While you use this tool in a one-way instructor-to-student mode, do you think that your use of _______ tool translates well to a collaborative environment? Why / why not?
    b. (for dissimilar activity) Can you think of a scenario where using this tool in a similar manner might be helpful for the entire course via the CTools course site?
        i. Can you think of any other examples?
        ii. Would you consider using this tool for your courses in the future? Why / why not?

6. Did you use any other kinds of technology for your course? Which ones?
    a. Why did you use these technologies?
    b. Did students comment on your use of these technologies?
        i. What did they say?
    c. Do you have any other comments about your use of technology for your course?

7. In the last survey, ___% of students responded that they thought that using a CTools project site made their grant proposal assignment more successful and ___% responded that they thought that using a CTools project site improved their grade.
    a. Did students make any comments to you about their use of CTools project sites?

        i. Can you relay any common themes or comments?
   b. Do you believe that using this kind of technology improved the quality of grant proposal assignments? How? Why?
   c. Would you advise your students to use CTools project sites for their group assignments in the future?
        i. Why?
        ii. Would you advise them to use a particular tool or set of tools? Which ones?
        iii. Would you advise them to use the various tools in a particular way? How? Why?
   d. Do you have any other comments about CTools project sites?

8. I want to thank you for being a great partner in this interdisciplinary project. Before we finish, do you have any comments about the project in general or your interest in participating in future interdisciplinary research projects?

Thank you for speaking with me today.

APPENDIX F: PROJECT SITE TRAINING WORKSHOP HANDOUT

CTools Project Site Training Session Handout

Steve Lonn – CTools Staff – slonn@umich.edu

Setting up your project site:

1. Login to CTools – Navigate to the My Workspace tab
2. Click "Worksite Setup"
3. Click "New" … Select "project website" … Click "Continue"
4. Enter a site title … Click "Continue"
5. Select the tools you want to use … Click "Continue"
6. Leave the next screen as-is … Click "Continue"
7. Click "Create Site"

Adding other people to your project site:

1. Click "Site Info" … Click "Add Participants"
2. Enter UMich people's uniqnames into the top box
   Enter non-UMich people's full email address (e.g., bob@yahoo.com) into the bottom box
3. Choose to either assign all new participants the same role or each person's role individually … Click "Continue"
4. Select the role(s) for the individuals … Click "Continue"
5. Select if you want to send the new participants a notification message … Click "Continue"
6. Click "Finish"

Add a logo to your project site:

1. Upload a .gif or .jpg file that measures no more than 100 pixels square to the Resources tool
2. Right-click (ctrl-click on Macs) on the title of the resource file and copy the URL to the clipboard
3. Click "Site Info" … Click "Edit Site Information"
4. Click the box after "Icon URL" and paste the URL from Resources … Click "Continue"
5. Click "Finish"

STEVE'S TOOL TIPS:

Resources:

- To turn on the Citation List creation option: Click "Options" … Click the "Citation List" check box … Click "Update"

- Email other group members that the file has been uploaded: Use the "Add Details" > "Description" box to describe the file or any changes you have made in the current version and then use the Email Notification option at the bottom

- Need to upload or download a lot of files at once? Click the "Upload-Download Multiple Resources" link and follow the instructions for setting up WebDAV on your machine

- Don't want to fuss with the Wiki tool? Create a new HTML or plain text document and collaboratively edit using the text editor within the Resources tool

Web Content vs. URL links in Resources

- If you have one website that you will need to reference or visit several times, use the Web Content tool to create a menu item on the left-hand menu bar

- If you are collecting websites for references or as interesting materials, I suggest you save these as URL links in the Resources tool.

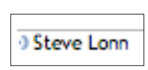
Schedule:

- Items added to your schedule on your project site will also appear on your My Workspace Schedule – a handy way to look for time conflicts

Announcements:

- To view the body of all announcements without clicking each individual announcement, click "Options" and select either the "sortable" or "list" view with announcement body

Chat Room:

- How do you know someone is in chat? There will be a little blue dot next to their name in the list of users below the left-hand menu 

Wiki:

- Enter the text "{recent-changes}" at the bottom of the Home page to view all wiki page changes in the last month

- To receive email notifications about wiki page changes, click "Watch"

Email Archive vs. Messages:

- If you want to use your normal email client (e.g., UM Webmail) and just save a copy of all messages sent to the group, use Email Archive

- If you think you will compose all of your messages within CTools, use Messages

Discussion vs. Forums:

- Forums is still being fine-tuned. For now, CTools staff recommends that you use the Discussion tool for threaded conversations

---

Have CTools Questions??

Check the online Help Guide: Click "Help" on the left-hand menu of any CTools screen

or

Email Steve: slonn@umich.edu

or

Contact CTools Support: Click "Contact Us" at the bottom of any CTools screen

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