COGNITIVE PRESENCE AMONG MATHEMATICS TEACHERS:

AN ANALYSIS OF TASKS AND DISCUSSIONS IN AN

ASYNCHRONOUS ONLINE GRADUATE COURSE

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ABSTRACT

Higher order learning, in terms of both process and outcome, is frequently cited as the goal of higher education (Garrison, Anderson, & Archer, 2000). However, the adoption of computer mediated communication in higher education has far outpaced our understanding of how this medium can best be used to promote higher order learning (Garrison, Anderson, & Archer, 2004). Researchers have examined quantitative components of computer mediated communication, but little work has been done to examine the cognitive aspects of online discussion. Those studies that do exist demonstrate inconsistent evidence of higher order learning in online discussions (Kanuka & Anderson, 1998; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000; Meyer, 2003). Researchers conjecture that this could be due to the nature of the tasks that instructors implement for discussion purposes (Arnold & Ducate, 2006; Meyer, 2004; Murphy, 2004; Vonderwell, 2003).

This study explored whether one component of instruction, the tasks assigned to students, had an effect on the level of cognitive presence that existed in the mathematical discussions of practicing mathematics teachers enrolled in an online graduate course. Through the method of content analysis, discussion transcripts were analyzed to look for evidence of higher-order learning based on the cognitive presence coding protocol developed by Garrison, Anderson, and Archer (2001). Seventeen students in a History of Mathematics course form the primary sample for this study. The results of the content analysis were triangulated with qualitative data from a questionnaire on student backgrounds and demographics and a post-course survey assessing student perceptions of their learning experiences.

The researcher concluded that the MATH 500 course discussions did provide evidence of higher order learning in terms of cognitive presence. Task type, as defined in this study, was not directly related to the levels of cognitive presence achieved in the course. This finding does not negate the possibility of such a relationship, but in this study the effects of task type could not be isolated from other features of the course structure and assignments.

CHAPTER 1

PROBLEM STATEMENT

Introduction

At universities across the country enrollments, course offerings, and availability of distance education have increased rapidly since the 1990s. Distance education can be viewed as the separation of student and teacher by space, but not necessarily time. During the 2000-2001 academic year, 89% of all public four-year degree-granting institutions offered distance education courses (National Center for Education Statistics, 2002). The primary role of networked computers in higher education has shifted to facilitating communication rather than presenting learning materials in a structured, pre-programmed form (Rourke & Anderson, 2005). Web-based online distance education in particular has exploded since the launch of the World Wide Web in 1992, with computer conferencing at the core of online education. Online learning encompasses all levels of education including K-12, post-secondary, and graduate, and also supports professional development. A wide array of disciplines are represented, including but not limited to, science-based courses (e.g., mathematics and chemistry), social science courses (e.g., psychology and sociology), and a variety of business courses. As stated previously, distance learning is growing at a phenomenal rate and can be found in nearly all areas of education, including workplace continuing education. Professional development programs for teachers and nursing students, as well as graduate programs for persons pursuing their MBAs, are also common.

Harasim (2000) defined computer conferencing, also known as computer mediated communication, as a medium that allows for social interaction, communication, and collaboration among students and instructors by means of exchanging messages through networked computers.

> Computer conferencing remains the "heart and soul" of online education, and presumably a discourse focus will always exist, for education is essentially about interaction, conceptual change, and collaborative convergence (Harasim, 2000, p. 51).

Computer mediated communication (CMC) is believed to have the potential to facilitate deep and meaningful learning (Garrison, Anderson, & Archer, 2000; Garrison, 2003; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000). Asynchronous online learning in particular possesses interactive and reflective properties that are related to higher order learning (Garrison, 2003; Harasim, 2000). Asynchronous refers to "anytime, anywhere" use of technology rather than requiring users to be present at the same time or in the same place (Benbunan, 2002). Participation is not constrained to fixed times and locations; instead, students and instructors choose when to contribute by sitting down at a computer and posting messages to an online computer conference. Asynchronous learning networks, more commonly referred to as ALNs, are the fastest growing form of distance education. Through asynchronous learning networks, educators and students are able to maintain meaningful communication with one another, but are afforded more flexibility.

The emergence of online learning environments such as ALNs led educators to recognize the need for a better understanding of the conditions and means for achieving effective learning in ALN contexts (Harasim, 2000). Harasim posed a critical question:

"How can the online environment support the conversations and shared explorations that form part of the user's active (co-)production of knowledge?" (p. 14). The permanency of computer conference transcripts allows for a plethora of research opportunities to explore this question. Asynchronous discussion transcripts have been and continue to be analyzed for evidence of higher-order learning using content analysis (Bullen, 1998; Kanuka & Anderson,1998; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000; Meyer, 2003; Pawan, Paulus, Yacin, & Chang, 2003; Schellens, Van Keer, & Valcke, 2005). The process of evaluating transcripts offers invaluable insights into the nature of learning and teaching in this increasingly popular educational medium (Garrison, Anderson, & Archer, 2001).

<center>Theoretical Framework</center>

The many modes of distance learning, the diversity of mathematical learning, and the nature of learning itself make it necessary to frame this study in a well-defined context. In terms of distance learning, this study concentrates on asynchronous online discussions. In terms of mathematical learning, the focus is on a single online class that is offered to mathematics teachers in a masters program combining content and pedagogy. In terms of the nature of learning, a combination of socioculturalism, based on the ideas of Lev Vygotsky, and the Community of Inquiry framework developed by Garrison, Anderson, and Archer (2001) form the theoretical basis for this study. Socioculturalism focuses on the importance of communication and social interaction within a culture to support knowledge construction. The Community of Inquiry (COI) model provides a

framework which transfers the principles of socioculturalism to the online learning environment. Combining the sociocultural perspective with the COI model frames this study within a modified social learning theory where learners construct knowledge collaboratively through discussion with others in the context of online computer mediated communication. Both theories are described in more detail below.

Socioculturalism

During the reform movement of the 1990s, constructivism was viewed by some researchers as the most influential and widely accepted philosophical perspective in mathematics education (Seldon & Seldon, 1996). The idea of meaning being constructed individually within a learner's mind, not transferred from one person to another, was central to constructivism. Mathematics education researchers also turned to the works of Lev Vygotsky for a new "social" theory of learning. Socioculturalism and socioconstructivism both build upon constructivism with an increased emphasis on the importance of communication and social interaction in knowledge creation. These terms are commonly used interchangeably, but the themes of Vygotsky's works in particular focus on the role of culture in the development of the mind. Through the use of a common language within a culture, social exchanges occur with others and new information is internalized so that it may be used independently by the individual at a later time. In terms of student learning, communication is a means by which students co-construct knowledge as they strengthen and expand their individual understanding (Wu, 2003) through interaction with more knowledgeable peers and instructors.

Social constructivists, among others, claim that computer conferencing positively influences cognitive development (Wu, 2003). Computers have provided a new cultural tool that provides increased opportunities for social interaction and communication through networking. It is believed that computer technology can be used by students to mediate and internalize their learning. Since students are now working in a new cultural context, from a sociocultural perspective this new setting needs to be examined as to the learning possibilities provided. Fortunately, the use of computer conferencing technology not only supports the social construction of knowledge but also simultaneously creates an archive of this interactive process (Kanuka & Anderson, 1998) that can be used for analysis of the learning process.

Community of Inquiry (COI) Model

From a sociocultural perspective, mathematics teaching and learning should involve collaboration and communication within a community of inquiry. The goal of true communities of inquiry is to nurture independent thinkers in an inter-dependent collaborative community of inquiry (Garrison, 2003). The Community of Inquiry (COI) model developed by Garrison et al. (2001) "was designed to guide the use of computer conferencing to support critical thinking in higher education" (Rourke, Anderson, Garrison, & Archer, 1999, ¶ 1), thus providing a framework for taking into account a sociocultural perspective within the new educational medium of online learning. The framework is consistent with constructivist approaches to learning in higher education (Garrison & Arbaugh, 2007) and clearly takes into account the social nature of learning. "Language use and learning interact in a spiraling fashion within communities of learners

where talking with more skilled members of the community enables the student to acquire some of their expertise and a language for operating within the domain" (Wu, 2003, p. 169).

The COI model consists of three elements that contribute to the overall learning experience: social presence, teaching presence, and cognitive presence. The social presence element of the COI model is viewed as the ability of students to project themselves socially and affectively into a community of inquiry (Rourke, Anderson, Garrison, & Archer, 1999), which is important due to the lack of physical presence that occurs in a face-to-face classroom. Teaching presence relates to the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes (Anderson, Rourke, Garrison, & Archer, 2001). Cognitive presence is defined as the extent to which participants are able to construct meaning through sustained communication (Garrison et al., 2000). Together these three elements form the Community of Inquiry; the total educational experience of students and instructors in an online setting.

Statement of the Problem

Higher order learning, in terms of both process and outcome, is frequently cited as the goal of higher education (Garrison et al., 2000), yet the adoption of computer mediated communication in higher education has far outpaced our understanding of how this medium should best be used to promote higher order learning (Garrison, Anderson, & Archer, 2004). Garrison (2003) noted that asynchronous online learning is here to stay

and is thus forcing educators to reflect on teaching and learning processes and on what constitutes effective learning in this environment. In his view, learning for educational purposes goes beyond simply accessing information and participating in chat rooms, and we need to ensure that online education is not stopping at this level, but is providing a medium where higher order learning occurs. In discussing the Community of Inquiry model, Garrison (2003) pointed to the issue of creating cognitive presence in online learning as an issue that requires much more research: "The literature is replete with articles and books discussing online learning from the perspective of social and teaching presence, but little progress has been made in understanding cognitive presence and higher order learning effectiveness online" (p. 50). Several studies have not found evidence of higher order learning in online discussions (Bullen, 1998; Kanuka & Anderson,1998; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000; Meyer, 2003; Pawan et al., 2003; Schellens et al., 2005). Researchers conjecture that this could be due to the nature of the tasks that instructors implement for discussion purposes (Arnold & Ducate, 2006; Edelstein, 2002; Garrison & Arbaugh, 2007; Meyer, 2004; Murphy, 2004; Vonderwell, 2003).

In short, a disconnect exists between the implementation of online distance education, specifically in the ALN format, and our knowledge of its effectiveness as a learning tool in education. The challenge is for researchers to design studies that inform the online instructional community about strategies and contexts that are capable of producing higher order learning in online discussions.

Purpose of the Study

The purpose of this study was to look for evidence of higher order learning, or cognitive presence, in an online learning context and to explore whether one component of instruction, the tasks assigned to students, had an effect on the level of cognitive presence that existed. In particular, this study explored the existence of cognitive presence in a semester-long course on the history of mathematics (MATH 500) taught through a Master of Science program for mathematics teachers. Because discourse is believed to be a powerful tool for cognitive development (Wu, 2003), discussion transcripts provided the principal source of data for the study.

Research Questions

The research questions this study sought to answer are:

1. Do the discussions generated in MATH 500 demonstrate evidence of higher level thinking in terms of cognitive presence?

2. What is the nature of the tasks that are implemented in MATH 500?

3. Is there evidence of a relationship between the tasks that are implemented in MATH 500 and the levels of cognitive presence observed in the corresponding discussions?

These questions were investigated by analyzing the online discussions from an online masters level course for mathematics teachers. Garrison et al.'s (2001) cognitive presence coding protocol was used to assess the level of cognitive presence that was evident in the discussion transcripts. Supporting data was also obtained from a

questionnaire, a survey, and an instructor interview. The objective was to ascertain if evidence of higher order learning existed within the discussions, and if so, whether the level varied according to the type of task that generated the discussion.

Significance of the Study

The advent of online distance education has far outpaced our understanding of its effectiveness in terms of learning. McLoughlin and Luca (2000) noted that "much current debate surrounds how to create optimal conditions in online environments for productive interactions that lead to higher order cognition and enable learners to develop as independent thinkers" (¶ 3). Bonk and Dennen (2003) suggested that instructors in higher education need frameworks that can help them maximize computer mediated communication as an instructional tool. They further observed that few empirical studies have made recommendations about pedagogy to online practitioners in higher education. Online teaching concerns are focused on the technological aspects of the software rather than on the theoretical and educational rationale for using it (McLoughlin & Luca, 2000). The need for further research to extend the educational community's knowledge of online learning transactions that result in meaningful and worthwhile learning is becoming critical (Kanuka & Garrison, 2004).

Since asynchronous learning networks make up a significant component of online learning, it is imperative to explore the effectiveness of ALNs in different disciplines in order to justify their use as an instrument of learning. This study addressed two important questions: 1) Is there evidence of higher order learning in the ALN environment? and 2)

Can the choice of student tasks influence higher order learning? The findings produced by this study offer mathematics educators valuable information about the types of activities that promote higher order learning in online asynchronous discussions.

Significant terms used in this study are defined below. The following chapter elaborates on the theory of socioculturalism, the Community of Inquiry framework, and other elements of the online learning research literature that contribute to the theoretical framework and methodology supporting this study.

Definition of Terms

- *Computer mediated communication (CMC)/computer conferencing* - The exchange of messages among a group of participants by means of networked computers for the purpose of discussing a topic of mutual interest (Gunawardena, Lowe, & Anderson, 1998).
- *Content analysis* - A research technique for the objective, systematic, quantitative description of the manifest content of communication ((Berelson, 1952, p. 519) in Rourke, Anderson, Garrison, & Archer (2000)).
- *Collaborative learning* - The instructional use of small groups so that students maximize their own and one another's learning.
- *Higher order learning* - Agreed by theorists to represent the capacity to go beyond the information given, to adopt a critical stance, to evaluate, to have meta-cognitive awareness, and to possess problem solving capacities (McLoughlin & Luca, 2000). Studies commonly use the phrases higher order learning/thinking,

(co-)construction of knowledge, critical thinking, and higher order cognition interchangeably. Their definitions vary slightly in meaning when defined by each researcher, but generally follow the idea of the higher order learning definition provided. This study will use the terms interchangeably.

- *Cognitive presence* - Represents all aspects of higher order learning in the online setting.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this study is to look for evidence of higher order learning or cognitive presence in an online learning context and to explore whether one component of instruction, the tasks assigned to students, has an effect on the level of cognitive presence that exists in the discussions.

This chapter begins by addressing two major learning theories, constructivism and socioculturalism, which significantly inform the study in terms of the theoretical framework it was founded upon. This is followed by a review of the research on the importance of communication in mathematics classrooms, and the use of asynchronous learning networks to communicate in online learning. Next is a review of the literature on mathematical and online tasks that are commonly implemented and form the basis of discussions. Together these three sections form a research base to ground the study's research questions. The final section adds to the theoretical framework basis and informs the study in terms of the Community of Inquiry model which provides a basis for the study's implementation in the online setting.

Constructivism, Socioconstructivism, and Socioculturalism

Constructivism has been viewed by some researchers as the most influential and widely accepted philosophical perspective in mathematics education (Seldon & Seldon,

1996). This was likely the result of the reform movement which began in the early 1980s - the same era in which constructivism came to light. The reform movement sought to influence mathematics education by stressing problem solving, reasoning, and communication in a technological world. The focus was no longer solely on getting the correct answers, but also on developing meaning and understanding mathematical processes.

McLoughlin & Luca (2000) claim that "every definition of constructivism refers to active knowledge creation and not reproduction of information" (¶ 19) which is the focus of mathematics education (Steele, 2001). Meaning is not transferred from one person's mind to another, but instead is constructed individually within the person's mind. The construction of knowledge is based on the previous experiences, beliefs, and knowledge of the individual (Kanuka & Anderson, 1998; Pantel, 1997). Thus, when a person is exposed to new information, he or she "understands and assimilates it in the context of his or her existing mental structures" (Pantel, 1997, ¶ 3).

This shift in focus to individual knowledge construction based on personal experience also shifts the role of teachers within the educational system. Learners are now responsible for expressing and justifying their mathematical thinking, and teachers are responsible for providing authentic activities that promote these practices. Teachers are expected to facilitate student learning rather than transmit knowledge to students (Mayers & Britt, 1995; Seldon & Seldon, 1996).

Constructivism is historically linked most often to Jean Piaget whose research focused on cognitive development. Most literature refers to Piaget's constructivism as the

individual construction of knowledge where the individual interacts with the environment (Bonk & Cunningham, 1998). Social constructivism, on the other hand, is historically linked to Lev Vygotsky, who also focused his research on cognitive development, but emphasized the influence of cultural and social contexts in learning (Kanuka & Anderson, 1998). Vygotsky believed that social interaction profoundly influenced cognitive development. Social constructivists believe that rather than knowledge being created individually, "knowledge is generated through social intercourse, and through the interaction we gradually accumulate advances in our levels of knowing" (Kanuka & Anderson, 1998, p. 3). Much of the literature focuses on this distinction of individual versus social knowledge creation in comparing Piaget and Vygotsky, but it is suggested by Cole (2007) that the theorists in fact had similar thoughts on knowledge construction. The main difference between them was that Vygotsky stressed the importance of culture on the development of the mind. In fact, Dillenbourg, Baker, Blaye, and O'Malley, (1996) do not link social constructivism with Vygotsky at all. Instead, they relate Vygotsky directly to socioculturalism.

Socioculturalism is a term very closely related to social constructivism and in fact, the two are sometimes used interchangeably (Bonk & Cunningham, 1998). It has its roots in constructivism but "focuses on the role of community and environment in the creation of knowledge as opposed to the internal negotiation of meaning" (Pantel, 1997, ¶ 5). Social constructivism emphasizes individual development within a social setting whereas sociocultural theory focuses on social interaction as the cause of individual cognitive change (Dillenbourg et al., 1996). Three major themes from Vygotsky's work

include his concept of development, the social origin of the mind, and the use of speech in development (Elliott, 2000). Where Piaget and other cognitive psychologists focused on the products of development, Vygotsky focused on the processes that caused them (Elliott, 2000; Goos, 2004). He felt that developmental processes were responsible for the transformation of biological processes into higher psychological functions (Elliott, 2000).

Another theme of Vygotsky's work was the social origin of the mind which states that development occurs on two separate planes: first in social exchanges with others – the inter-psychological plane, and second within the person themselves as inner speech – the intra-psychological plane (Dillenbourg et al., 1996; Goos, 2004). This process of taking new information experienced within a social context and internalizing it for use independently at a later time is referred to as internalization (Bonk & Cunningham, 1998). Internalization occurs within Zones of Proximal Development (ZPD) which bridge the gap between the capabilities of a learner when working alone, and the capabilities of a learner when assisted by more knowledgeable counterparts (Bonk & Cunningham, 1998; Steele, 2001).

The last theme of Vygotsky's work involves the importance of speech in development. Social and individual psychological activity is believed to be mediated by the tools of the culture (Bonk & Cunningham, 1998). Language was the tool of specific interest to Vygotsky (Cole & Wertsch, 2002). In this view, development is dependent upon the cultural origins and artifacts in one's environment such as speech and writing which are used to mediate the environment (Bonk & Cunningham, 1998).

The themes of Vygotsky's work are central to sociocultural theory, and

sociocultural theory in turn has become a major trend in mathematics education research

(Cobb, 1994). Simply put, socioculturalism built upon constructivism with an increased

emphasis on the importance of interaction and communication. A study by Steele (2001)

looked at a specific mathematics instructor's teaching strategies whose belief was that

students could create mathematical meaning through communication with one another.

Steele found that the instructor's strategies were sociocultural in nature (if one was to

choose a theoretical perspective to justify her teaching style). Students explored,

reflected, and communicated their ideas, while they made connections from their

ordinary personal language to formal mathematical language. These strategies are clearly

in line with a sociocultural approach to mathematics teaching that focuses on

collaboration and discussion among students with a goal of providing students with the

opportunity to create meaning. Using Vygotsky's theories, students in a mathematics

class like that of Steele's study have an ability to use their current knowledge and past

experiences to communicate with more capable peers and/or a teacher. Through this

process they internalize the mathematical language of the culture they are involved in for

use in creating mathematical meaning and independently justifying and explaining

mathematical concepts in the future. Steele (2001) pointed out that students who share

their reasoning about ideas with others, and in turn listen to others share their thinking,

create understanding of culturally established mathematical practices.

A study by Goos (2004) also looked at the teaching and learning practices of a

mathematics classroom based on sociocultural theories which "offer mathematics

education researchers a useful theoretical framework for analyzing learning as initiation into social practices and meanings" (p. 281). The Zone of Proximal Development was the basis of the study, and was used to facilitate participation of the class in a community of mathematical inquiry. The focus was once again on the creation of meaning by the students through collaboration and communication. Clearly, the sociocultural approach has the "potential to improve understanding of how learners can be pulled forward into mature participation in communities of mathematical practice" (Goos, 2004, p.283).

Computers provide a new cultural tool which tremendously increases the opportunities for social interaction, a major premise of socioculturalism. Students are able to use computers for collaboration with others, whereas collaboration was once only possible in face-to-face situations. This creates a new cultural context in which students can take part. To understand learning from a sociocultural perspective this new setting in which the learning occurs must be examined (Bonk & Cunningham, 1998). Bonk and Cunningham (1998) attempted to do this by looking at the theoretical perspective of socioculturalism in terms of collaborative technology. Their analysis found that "a socio-cultural view on collaborative tools explicitly points to the social origin of higher mental functions, the distributed nature of learning and problem solving, and the importance of technology tools in mediating individual and cultural development" (p. 45) and that "ongoing developments in computer supported collaborative learning technology therefore make possible the embodiments of sociocultural theory not possible in Vygotsky's days" (p. 45). The technological changes that have rapidly occurred, and keep occurring, have resulted in a plethora of human learning possibilities when viewed

from a sociocultural perspective (Bonk & Cunningham, 1998). For instance, a study by

Weasenforth, Bieenbach-Lucas and Meloni (2002) found that threaded discussions have

enormous potential in realizing constructivist principles which, as demonstrated earlier,

are rooted within the principles of socioculturalism.

<center>Communication</center>

The reform movement of the 1990s was in part fueled by the publication of the

Curriculum and Evaluation Standards released by the National Council of Teachers of

Mathematics (NCTM) in 1989. The intent of this document was to establish some basic

guidelines for the teaching of mathematics in elementary and secondary schools. After

the publication of supporting documents in 1991 and 1995, the NCTM Standards were

revised and re-released in 2000 under the title *Principles and Standards for School*

Mathematics (PSSM). The NCTM claims that the PSSM "represent our best current

understanding of math teaching and learning and the contextual factors that shape them"

(NCTM, 2000). A key feature of mathematics reform reflected in the PSSM document is

an emphasis on communication which naturally calls for a shift in the pedagogy of

mathematics education (Goos, 2002; Silver & Smith, 1997).

Unfortunately, the conventional approach to teaching mathematics, which

emphasizes silence, memorization, and imitation, gives little or no attention to the role of

communication in students' learning (Silver & Smith, 1997). A study by Stage (2001) of

undergraduates in a finite mathematics class found that ability to generate understanding

and meanings about the mathematics of the class was not valued. Students who could

manipulate symbols and use algorithms to find an answer were considered the high achievers of the class, even though they could not explain what they were doing.

The reform movement in K-12 curriculum and the NCTM standards and related documents, have played a major role in identifying communication as essential to mathematics education. Links between mathematical reasoning and communication are central to the reform movement (Peressini & Knuth, 1998). From this movement has come research focusing on what a reform-oriented classroom with a focus on mathematical communication should look like (Forman & Ansell, 2001; Manouchehri & Enderson, 1999; Silver & Smith, 1997; Williams & Baxter, 1996). Research suggests that a critical factor in creating a discourse community within the classroom is the establishment of a classroom culture where communication is central to the teaching and learning of mathematics (Manouchehri & Enderson, 1999; Silver & Smith, 1997; Williams & Baxter, 1996).

The new social norms in a reform-based classroom culture, with an emphasis on communication as a learning tool, have resulted in altered teacher and student roles (Manouchehri & Enderson, 1999; Silver & Smith, 1997; Williams & Baxter, 1996). Students are expected to construct knowledge based on personal experience and through social interaction and are now held responsible for justifying their mathematical thinking (Forman & Ansell, 2001; Manouchehri & Enderson, 1999; Mayers & Britt, 1995; Seldon & Seldon, 1996; Williams & Baxter, 1996). They build upon peers' and teachers' thoughts and explanations as well as their own thoughts and in the process acquire a deeper understanding of mathematics (Perissini & Knuth, 1998). Students must come to

understand that mathematics is no longer just about using algorithms and finding the right solution, but about finding meaning (Forman & Ansell, 2001; Manouchehri & Enderson, 1999; Peressini & Knuth, 1998; Williams & Baxter, 1996). Teachers in turn are now responsible for providing authentic activities that provide a basis for rich conversations and for facilitating learning rather than transmitting knowledge through lecture-style teaching (Forman & Ansell, 2001; Manouchehri & Enderson, 1999; Mayers & Britt, 1995; Seldon & Seldon, 1996; Silver & Smith, 1997; Williams & Baxter, 1996). In reform-based classrooms, teachers are not viewed as the authority, but as facilitators who help students take ownership of their learning (Manouchehri & Enderson, 1999; Williams & Baxter, 1996).

Although research has been quick to point out the characteristics of a reform-oriented mathematics classroom rich in communication, such classrooms are not necessarily prevalent in schools across the United States. The NCTM Principles and Standards identify the importance of communication in learning and understanding mathematics (Steele, 2001), but there is still a problem with implementation of the vision. Discourse is an area of the standards that has been difficult for teachers to deal with, but it is believed that "once a teacher has seen students defending their mathematical ideas, questioning other students' ideas, and helping clarify mathematics to one another, the importance of discourse becomes clear" (VanZoest & Enyart, 1998, p. 152).

For teachers who have not experienced active classroom discourse or do not understand its importance, creating a classroom rich in discourse can be a problem (VanZoest & Enyart, 1998). Research has looked to establish ways in which higher

education can help current and future teachers become conscious of the use of communication as a tool for developing students' understandings and helping students develop practices that foster communication (Brendefur & Frykholm, 2000).

One such area examined is the role played by univocal and dialogic discourse in professional development and pre-service secondary mathematics courses. Univocal discourse is used to convey meaning from one person to another, while dialogic discourse is used to create new meaning (Peressini & Knuth, 1998). A study by Blanton (2002) created a classroom experience for pre-service mathematics teachers where dialogic discourse was stressed. Students led the conversations and the teacher posed questions in order to clarify or extend students' thinking. Students were found to develop a more complex understanding of the mathematics content through the dialogic discussions and stated their intentions to foster dialogic discussions in their future classrooms.

However, good intentions do not always translate into good practice, as was shown in a study by Peressini & Knuth (1998). Teachers in this study were participating in a professional development class that was intended to expand their knowledge of discrete mathematics. In the learner role, they were dialogic in their discourse as they struggled to grasp the complexities of the content. But in returning to their classes to implement the new content, they became more authoritarian and more univocal in nature in the role of teacher. Thus, even when teachers understand and value mathematical communication and reform oriented teaching methods, they may still naturally adhere to a traditional way of teaching (Brendefur, & Frykholm, 2000).

How then can discourse be fostered within the mathematics classroom? Researchers believe that modeling appropriate discourse within the pre-service undergraduate classroom and within professional development activities is an important first step (Peressini & Knuth, 1998). The mathematics classroom is a unique place for pre-service teachers and current educators to practice and reflect on reform oriented teaching, especially in the area of communication (Blanton, 2002; Peressini & Knuth, 1998). According to Stage (2001) a vicious cycle can begin with undergraduates who do not learn mathematics with meaning, leading to either teachers who teach without requiring mathematical understanding or mathematics graduate students and professors who do not understand the meaning themselves and thus do not require a true understanding from their students.

Communication, with the goal of building meaning and understanding of mathematical content, has thus far been discussed in the context of oral communication in face-to-face classrooms. Communication through writing can be equally effective (if not more so) in the eyes of some researchers. Garrison et al. (2000) believe that text-based communication is preferable to oral communication when the end objective is to promote understanding in the form of higher order learning. Their stance is that text-based communication not only provides time to reflect, but "the permanent and precise nature of written communication also allows if not requires reflection to interpret and construct meaning" (Garrison, 2003, p. 50).

The NCTM Principles and Standards point to the ability of students to solidify their thinking by clarifying their own thoughts when reflecting on their work (NCTM,

2000). Mathematical understanding is developed when students' critical thinking is put into words, whether orally or in writing (Masingila & Prus-Wisniowska, 1996). Thus each mode of communication allows researchers to gain insight into students' mathematical understanding.

<u>Online Learning</u>

<u>Traditional versus Online Classrooms</u>

Online or Web-based learning is a type of distance education that focuses specifically on the use of the Internet for learning, usually in an environment that emphasizes computer mediated communication (CMC). An increasing number of traditional face-to-face classes are being duplicated, if not replaced, by online learning at many post-secondary institutions. One common reason students choose to take an on-line class is the convenience (Freeman, 1997; Kitchen, McDougall, 1998-99; Leonard & Guha, 2001; Riviera, McAlister, & Rice, 2000; Shea, Motiwalla, & Lewis, 2001; White, 2001). Students that choose to take online classes like the flexibility of the online learning experience and place high value on their control over the pace and timing of their learning (MacGregor, 2001; Roblyer, 1999).

Due to the rapid increase of Web-based courses in the 1990s, numerous research studies focused attention on the differences between traditional face-to-face classes and online learning courses in terms of student satisfaction and learning. Merisotis and Phipps (1999) conducted a meta-analysis of studies done in the 1990s on differences between college-level distance education and traditional education. The researchers concluded that

distance learning courses compare favorably with face-to-face instruction and students have high satisfaction levels regardless of the type of technology used. Other studies concerned specifically with online learning also showed that students were equally satisfied with their online learning experience and sometimes even more satisfied than with their face-to-face classroom experiences (Basile & D'Aquila, 2002; Leonard & Guha, 2001; MacGregor, 2001; Sandercock & Shaw, 1999).

Although students are satisfied, they feel more challenged by online classes (Leonard & Guha, 2001; MacGregor, 2001). The time required of online classes as well as timelines set by the instructor are major components of this challenge. Students find online discussions time consuming because of the need to check for and read their peers' postings and because of the time it takes to think about a response and prepare it (Meyer, 2003). Tight timelines set by the instructors add to the complexities of coordinating and moderating an online seminar (Kitchen & McDougall, 1999).

Although the online classes are viewed as more challenging than face-to-face, students recognize the opportunity online classes give them to participate (Leonard & Guha, 2001; Meyer, 2003; Thiele, Allen, & Stucky, 1999). Students like the sense of control they have in being able to share their insights whenever they like, as opposed to a face-to-face setting where conversations tend to go in a new direction before everyone is able to contribute (Meyer, 2003). They also like the increased comfort they have in asking questions and disagreeing with instructors (Thiele, Allen, & Stuckey, 1999). Shy students tend to find online discussions liberating (Bullen, 1998).

With the advent of online learning came a need for researchers to analyze the degree to which students in Web-based courses were learning in comparison to their face-to-face counterparts. Typically learning was measured in terms of grades or self-reported data. Grades were found to be higher for online students in studies by Neuhauser (2002), Benbunan-Fich and Hiltz (2002), and Sandercock and Shaw (1999), and similar in a study by Rivera, McAlister, and Rice (2000). Questionnaires and interviews also revealed that students perceive their online learning experience as equal to that of face-to-face situations (Benbaunan-Fich & Hiltz, 2002; MacGregor, 2001; Neuhauser, 2002).

In some studies students viewed the quality of the discussions they had in traditional classrooms as better, yet the products the students produced as a result of online discussions were just as good if not better (Benbunan-Fich, Hiltz & Turoff, 2001; Ocker & Yaverbaum, 1999). Asynchronous discussions in a study by Benbunan-Fich, Hiltz, and Turoff (2001) were found to be richer in terms of the topics raised and the ideas produced by the students. The result was higher quality work by the online students when compared to the reports of face to face students.

Potential for Knowledge Construction in the Online Environment

Asynchronous computer mediated communication (ACMC) is the main form of communication used in online learning. In this mode, participation is not constrained to certain times and places; instead students decide when they will participate by posting messages to a discussion forum for others to read and respond to. Computer mediated communication is unique because of its ability to support high levels of responsive, intelligent interaction between teachers and students while simultaneously providing high

levels of flexibility of time and place to engage in the activity (Rourke et al., 1999).

Online conferencing is more than a means to access information, it is believed to have the

potential to facilitate deep and meaningful learning (Garrison et al., 2000; Garrison,

2003; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000). This is due to the

interactive and reflective properties that asynchronous online learning in particular

possesses (Garrison, 2003; Harasim, 2000). Asynchronous learning encourages reflection

while connectivity provides unique opportunities for collaboration (Garrison, 2003). Aviv

(2000) described an asynchronous learning network as "cooperative learning enhanced by

extended think time" (p. 53) thus further supporting the ideas of connectivity and

reflection afforded by ACMC.

Face-to-face learning experiences have been the norm for collaboration, but the

advent of computer conferencing within the academic community has expanded

collaborative possibilities (Ocker & Yaverbaum, 1999). Collaborative learning

experiences are provided at the convenience of the learner, resulting in more interaction

and students asking more questions (Robles & Braathen, 2002). In fact, in some studies

greater interaction has been evidenced in online learning than is typically found in face-

to-face environments (Garrison, 2003; Lavooy, & Newline, 2003). Littleton & Whitelock

(2005) believe the importance of interaction for learning lies within the notion that

"knowledge and understanding are constituted in and through interaction" (p. 148).

Interaction is seen as central to an educational experience and is a primary focus in the

study of online learning (Garrison & Cleveland-Innes, 2005). In a study researching

interactions and cognitive engagement in asynchronous discussions, Zhu (1996) found

that online discussions with interactions among students and instructors facilitate knowledge construction.

Studies suggest that online learning environments provide students with more time to pause and thoughtfully reflect before making contributions to a discussion (Wu, 2003). "In contrast to the spontaneous verbal communication of face-to-face learning contexts, the asynchronous and largely written communication of asynchronous online learning would appear to provide the conditions that encourage if not require reflection" (Garrison, 2003, p. 50). The time and space independence of asynchronous computer mediated communication provides a lag time for reflection (Arnold, 2006). Due to the permanency of postings and availability for others to view them, asynchronous conferencing tends to naturally lend itself to reflective practices on the part of students (Kanuka & Garrison, 2004).

<u>Evidence of Knowledge Construction in the Online Environment</u>

McLoughlin and Luca (2000) believe online conferencing can potentially play a major role in developing higher order thinking because of the reflection potential allowed by asynchronous discussions. However, despite the potential for higher order learning that exists in the asynchronous conferencing environment, researchers consistently find that online learners have great difficulty moving beyond the initial stages of sharing and comparing of information to collaborative knowledge construction. In the early stages of online learning research, transcripts were typically used for counting the number of student postings, but researchers have since become more concerned with the quality of

postings rather than their quantity. Content analysis is a technique which is often used to analyze the transcripts of asynchronous computer mediated discussions in formal educational settings with the aim of revealing information that is not situated at the surface of the transcripts (DeWever, Schellens, Valcke, & Van Keer, 2005). Content analysis allows researchers to explore the question posed in many studies: "Is there evidence of knowledge construction among learners in an asynchronous online environment as revealed by their discussions?"

Content Analysis Schemes

The pioneering content analysis work of Henri, along with the coding protocol for knowledge co-construction developed by Gunawardena and others, are described below. These examples provide a glimpse of how content analysis is used to answer questions similar to the one posed above. They also showcase two well-known content analysis schemes. A third content analysis scheme to be used in this study will be described in detail later in this chapter.

The instrument designed by Henri (1992) is most cited as a starting point for content analysis schemes. Henri was interested in how the cognitive level of one's electronic contribution related to student understanding, reasoning, and the development of critical thinking and problem solving skills (Hara, Bonk, & Angeli, 2000). Five dimensions exist within Henri's scheme, which is based on a cognitive approach to learning: 1) participation in terms of a quantitative posting rate; 2) social statements not related to the subject matter; 3) interactive statements versus independent statements; 4) cognitive statements based on elementary clarification, in-depth clarification, inference,

judgment, and strategies; and 5) meta-cognitive knowledge and skills exhibited. A thematic unit, rather than a full message, was used as the unit of analysis. Thus, a message that contains more than one idea or theme might be divided into several units of meaning according to each idea expressed. The instrument was not empirically tested by Henri, resulting in a lack of inter-rater reliability statistics for comparison.

The major criticism of Henri's model is that it does not account for co-construction of knowledge by a group of individuals (DeWever et al., 2005). Henri's model is based on a teacher-centered instructional paradigm which is inappropriate in a constructivist learning environment based on shared construction of knowledge (Kanuka & Anderson, 1998). Gunawardena, Lowe, & Anderson (1998) proposed a learner-centered model constructivist in nature, called the Interaction Analysis Model (IAM), where the active social construction of knowledge goes through a five-phase process: 1) sharing and comparing of information, 2) discovery and exploration of dissonance among ideas, 3) negotiation of meaning and/or co-construction of knowledge, 4) testing and modification of proposed synthesis or co-construction, and 5) applications of newly constructed meaning. Grounded theory research methods were used to develop the model based on a socioconstructivist theoretical framework (Marra, 2006). The unit of analysis used by Gunawardena et al. was the entire message. Inter-rater reliability statistics were not reported by the authors (DeWever et al., 2005). Numerous researchers have applied the IAM to their studies successfully with varying results.

Other content analysis schemes that have been created by researchers to investigate critical thinking and knowledge construction in terms of social learning

include those of Newman, Webb, and Cochrane (1995) and Zhu (1996). Newman et al. did not provide reliability data in their study of their coding protocol. They claimed that coding relies on the subject knowledge of an expert in the domain, making it somewhat undesirable to implement. Newman et al. also used themes as the unit of analysis. In their coding scheme, phrases, sentences, paragraphs, and/or entire messages could be analyzed, leading to problems with reliability. Similarly, Zhu did not report reliability data in her study. She also stated a need for those conducting content analysis to have familiarity with the content area that drives the discussion being analyzed.

The two content analysis schemes discussed above are both relevant to the social construction of knowledge and have been in use for at least ten years, allowing time for replication and extension by both their authors and other researchers. Despite the availability of these and other reputable content analysis schemes, researchers continue to create their own instruments in order to suit their own research needs. Rourke et al. (2000) emphasize the need to replicate existing content analysis schemes and instruments (including their own) in order to strengthen their validity. They further note that thesis advisors typically discourage the construction of new content analysis instruments due to the sheer time commitment involved in building a valid tool.

<u>Content Analysis Studies</u>

Anderson et al. (2001) noted that a widely documented problem in computer conferencing is the difficulty of progressing beyond basic information sharing and on to knowledge construction, including the application and integration of ideas. Other research studies support this statement (Bullen, 1998; Kanuka & Anderson, 1998;

Littleton & Whitelock, 2005; McLoughlin & Luca, 2000; Meyer, 2003; Pawan et al., 2003; Schellens et al., 2005). These studies used various content analysis schemes to analyze the level of higher order learning that occurred in asynchronous online discussions. All studies cited a lack of higher levels of knowledge construction as interpreted by the particular content analysis scheme they chose to implement.

The apparent inability of discussion participants to critically build upon one another's ideas constructively within online discussions could be due to many factors, including: the complexity of issues raised (Kanuka & Anderson, 1998; Meyer, 2003); lack of student skill or information to propose a resolution (Bullen, 1998; Meyer, 2003); or missed opportunities on the part of the faculty to press for resolution (Meyer, 2003, 2004). Construction of knowledge may also simply be an unobservable activity or may occur long after the discussions are closed (Kanuka & Anderson, 1998). An increase in student awareness as to the purpose of online activities (Bullen, 1998; Kanuka & Garrison, 2004; Pawan et al., 2003) and a reassurance that participation will result in attainment of learning goals are necessary (Anderson et al., 2001; Kanuka & Garrison, 2004). Another common conjecture is that the nature of the tasks assigned in an online course may affect the level of the corresponding discussion (Meyer, 2004). The nature of tasks and their relationship to higher-order learning will be examined in the next section.

Tasks

Much remains to be learned about the implementation of online learning activities that can facilitate the development of a meaningful educational experience. Learning

strategies that are effective at facilitating higher order learning in a face-to-face context do not work as effectively in an asynchronous online course (Kanuka & Garrison, 2004). Thus, researchers need to develop online conferencing tasks that provide opportunities for extended communication and knowledge construction (Hara et al., 2000) in the online medium. In the following sections, research on mathematical tasks will be reviewed, along with research that focuses specifically on tasks and learning designs in the context of an online learning environment.

<u>Mathematical Tasks</u>

The selection or creation of a well developed task is believed to have the ability to stimulate discourse that can lead to establishing a mathematical discourse community and in turn lead to a greater mathematical understanding on the part of the students (Silver & Smith, 1997; Van Zoest & Enyart, 1998). In order to encourage mathematical discourse the focus should be on worthwhile tasks that engage students in thinking and reasoning about important mathematical ideas (Silver & Smith, 1997; Van Zoest & Enyart, 1998). Worthwhile tasks include those that are accessible to multiple solution methods and representations, and require justifications rather than answers (Silver & Smith, 1997; Stein, Grover, & Henningsen, 1996). These kinds of tasks require students to impose meaning and structure, make decisions about what to do and how to do it, and interpret the reasonableness of their actions and solutions (Stein et al., 1996).

The tasks that are defined and structured by instructors in mathematics classrooms highly influence the kinds of thinking processes in which students engage which in turn influences student learning outcomes (Anderson et al., 2001; Doyle, 1988; Stein et al.,

1996). "The focus for tasks involving higher cognitive processes is on comprehension, interpretation, flexible application of knowledge and skills, and assembly of information from several different resources to accomplish work" (Doyle, 1988, p. 171). Although most curriculum guides are framed in terms of understanding and meaning, few opportunities are provided for students to engage in tasks such as those described (Doyle, 1988).

Much of the research that focuses specifically on mathematical tasks refers to tasks in terms of mathematical content rather than pedagogy. A study that incorporates both aspects was conducted by Crespo (2006). A group of elementary teachers formed to provide teachers with a chance to work together to develop their own mathematical understanding as well as that of their students was observed. During discussions, mathematical tasks were either content-focused or pedagogy-focused. Discussions that focused on student work were found to provide opportunities to share and listen to one another's ideas. New ideas were not formed in terms of their practices as a teacher. Conversely, when working on mathematical tasks the teachers functioned as a community and were more exploratory in nature. The focus of the task resulted in clearly differing types of interactions and communications among the practicing teachers.

Doyle (1988, p. 169) identified the concept of an academic "task" by calling attention to four aspects: 1) a goal state or end product to be achieved, 2) a set of conditions and resources available to accomplish the task, 3) the operations involved in assembling and using resources to reach the intended goal, and 4) the importance of the task in the overall system of the class. His studies of academic tasks in the mathematics

classroom are based on the premise that the students' work, which is largely defined by the tasks assigned, provides a context for students' thinking during instruction and eventually in their understanding of the domain itself.

Doyle's goal in studies conducted in English, mathematics, and science classes was to identify the nature of the academic tasks used in the classrooms and their management in the classroom. Doyle categorized academic tasks into two broad categories: familiar and novel. Familiar tasks have predictable outcomes with little ambiguity about how to proceed with the task. Novel tasks on the other hand, require students to make decisions about how to proceed and what end product to produce implying high cognitive and emotional demands. Doyle found that work flow in the classroom is smooth and well ordered when teachers implement familiar tasks, in contrast to novel task implementation which results in activity that is slow and bumpy. This leads to teacher simplification of novel tasks by redefining or simplifying task demands, resulting in familiar tasks in the end. In terms of the mathematics classroom, these actions can limit students' opportunities for creating meaning and understanding by inadvertently emphasizing that remembering solution processes and quickly solving problems with the needed aid of a teacher is what is needed in the learning of mathematics.

Stein, Smith, Henningsen, & Silver (2000) also researched mathematical tasks, building upon the ideas set forth by Doyle (1988), looking in particular at the cognitive demands of tasks. They also believed that what students learn is dependent on the level and kind of thinking in which students engage as a result of the task implemented. Tasks with a lower-level cognitive demand that require students to perform a memorized

procedure in a routine manner lead to one type of opportunity for student thinking. Tasks with a higher-level cognitive demand that require engagement with concepts and that stimulate students to make purposeful connection to meaning or relevant mathematical ideas lead to a different set of opportunities for student thinking. Studies by Artz and Arthur-Thomas (1992) and Hiebert and Wearne (1993) back this idea. Each study found the type of mathematical task implemented influenced the cognitive processes in which students were engaged.

Stein et al. (2000) point out that there is still a place for lower-level tasks in the mathematics curriculum, but that focusing on these tasks exclusively "can lead to a limited understanding of what mathematics is and how one does it" (p. 15). Regular engagement with tasks that lead to deeper understandings regarding mathematical processes, concepts, and relationships are also needed to ensure students can apply what they've learned, and know when to apply it, in similar situations.

Unfortunately, the cognitive demands of tasks are not necessarily maintained once they are implemented in the classroom (Henningsen & Stein, 1997; Doyle, 1988; Silver & Smith, 1997). Henningsen & Stein (1997) identified three factors that led to the inability of mathematical tasks to remain at the cognitive demand level intended at implementation: time allotted, task inappropriateness, and removal of challenging aspects of the task. Hiebert & Wearne (1993) similarly found a connection between time spent on tasks and increased student learning opportunity. The removal of challenging aspects of the task on the part of teacher, as discussed in Doyle's (1988) findings above, clearly have an effect on the cognitive processes in which students engage.

Online Tasks

Garrison (2003) stated that a shift in our thinking from that of dispersing information to students is needed to create principles and guidelines for learning effectively online. Collaborative construction of meaning and understanding among students is needed; the challenge is to design learning activities that integrate both reflection and collaboration (Garrison, 2003; Kitchen & McDougall, 1988-89). The belief is that students who engage in collaborative tasks and share, explain, and elaborate upon concepts, participate in socio-cognitive interactions that lead to construction of new knowledge (Kanuka & Anderson, 1998; McLoughlin & Luca, 2000).

In accordance with the discussion of worthwhile mathematical tasks, tasks that are engaging and cognitively demanding are also needed in the online environment in order to support higher order learning (Garrison, 2003; Oliver & Herrington, 2001). Authentic tasks with a real world relevance facilitate student interaction in giving the students a sense of meaning and purpose while engaging with the task and result in social negotiation of meaning (Bonk & Cunningham, 1998; Wu, 2003). Many pedagogically and instructionally interesting activities exist for use in the online learning environment (Bonk & Dennen, 2003).

In a survey of college faculty on their perceptions of online learning, faculty stated the need for pedagogical tools and ideas that would foster greater critical and creative thinking of their students in the online setting (Bonk & Dennen, 2003). Unfortunately, according to Bonk & Dennen (2003), "there is a dearth of knowledge about pedagogical tools and strategies" (p. 338) for online learning, resulting in a need

for research based pedagogical frameworks. They pointed to the research of Ron Oliver and his colleagues, who are one of the few groups that have extensively studied online pedagogy. They stated "Oliver's leadership role is vital in promoting the Web as a learning environment based on socioconstructivist instructional design principles and practices" (p. 339).

A book written by Ron Oliver and Jan Herrington entitled *Teaching and Learning Online: A Beginner's Guide to e-Learning and e-Teaching in Higher Education* (2001) encompasses the central ideas of Oliver's vast research concerning online pedagogical techniques. Six learning designs are described which serve as frameworks that can be used to guide the design and choice of learning tasks in an online course. They include: situated learning, problem-based learning, case-based learning, project-based learning, inquiry-based learning, and role-playing. The designs were chosen because they provide a setting that supports knowledge construction in the following ways (p. 77):

- provides experience in the knowledge construction process

- provides experience with multiple perspectives

- embeds learning in realistic contexts

- encourages ownership and voice in the learning process

- embeds learning in social experiences

- encourages use of multiple modes of representation

- develops self awareness in the knowledge construction process

Each learning design is described further below based on Oliver and Herrington (2001).

"Situated learning describes a learning design which places a strong emphasis on bridging the gap between the theoretical learning that occurs in the formal instruction of the classroom and the real-life application of the knowledge in the work environment" (p. 78). Situated learning stresses the issue of achieving authenticity in learning and involves high degrees of student-centered activity. Suitable examples from real-world situations are not enough. Instead a single complex task to be completed over a sustained period of time that is "all-embracing" is necessary.

"Problem-based learning involves presenting students with a real-life problem immersed in a context which is relevant to professional practice" (p. 81). Complex problems are used to challenge students to apply their knowledge and determine the best outcome. Activities are generally authentic and reflective of the types of problems students will face in workplace settings and some degree of planning and investigation is needed when engaging in the activities.

Case-based learning is a form of problem-based learning where students work through a realistic case relevant to their discipline, either individually or collaboratively, and make decisions about the best course of action. The specific knowledge of previous experiences with other past cases is applied to the new problem situation.

Project-based learning is similar to problem-based learning in that it employs authentic and constructivist approaches, but project-based learning has an end product in mind whereas problem-based learning revolves around ill-structured problems. Learners are involved in the design and creation of products, usually collaboratively, which

"enables students to work meaningfully with knowledge and information in tasks which contain elements of problem-solving and strategy formulation" (p. 87).

"Inquiry-based learning describes a learning design where students are faced with an open-ended task for which they must formulate investigative questions, obtain factual information, and then build the knowledge that enables them to answer the original questions" (p. 90). This form of learning emphasizes research, critical thinking, and multi-disciplined study in order to achieve desired course outcomes. Inquiry-based learning requires greater support of the teacher. Typically students need to observe and question, present explanations, devise and conduct testing of theories, analyze data, draw conclusions, or design and build models. "This design places a task or some form of inquiry ahead of the content and gives a context for learners to engage with the material they may previously have been required to read" (p. 91).

"Role-playing is a learning activity where students assume characters within a chosen context and carry out roles in the conduct of a predetermined scenario" (p. 93). Role-plays are used extensively in education in face-to-face modes and have now moved to technology-mediated forms. They challenge students to demonstrate a range of negotiation, research, problem solving, planning, collaboration, and other communication skills.

Each design provides its own opportunities for learning and is distinct in some way from the others, although many similarities exist. Inquiry and project-based learning for example, are similar to problem-based learning, but the task driving the activity and the form of solution required as an end product vary.

Oliver, in working with McLoughlin (1999) also described a series of activities that are involved in problem-based learning: information seeking, critical thinking, collaboration, and problem solving. Information seeking refers to tasks that require students to seek information from sources to create an answer that reflects current thinking and knowledge among the plethora of information resources available. Critical thinking refers to using this information to explore the options and possibilities available in developing a solution. Collaboration refers to tasks that require students to work together to organize themselves in a product manner so that deadlines and schedules are met while being adaptive and flexible with others. Problem solving involves using initiative and intellects to consider the form the solution will take and to consider ways in which the solution can be expressed concisely and succinctly.

These activities provide strong support in developing the following key skills desired of university graduates (Oliver & McLoughlin, 1999, ¶ 7):

- skills that students need to develop to become successful and self-sufficient learners (management of self)
- the development of intellectual and imaginative powers, understanding and judgment, problem solving skills, critical thinking skills, and an ability to see relationships (management of information)
- personal and interpersonal skills needed for communication, cooperative and collaborative work, and leadership (management of others)
- skills required for successful work practices including time management, task management leadership, and self evaluation. (management of task)

Community of Inquiry Model

"The Community of Inquiry model was designed to guide the use of computer conferencing to support critical thinking in higher education" (Rourke, Garrison, Anderson, & Archer, 1999). The model of a Community of Inquiry (Figure 1) assumes that learning within a computer mediated conferencing environment occurs when three core elements interact: social, teaching, and cognitive presence (Garrison et al., 2000).
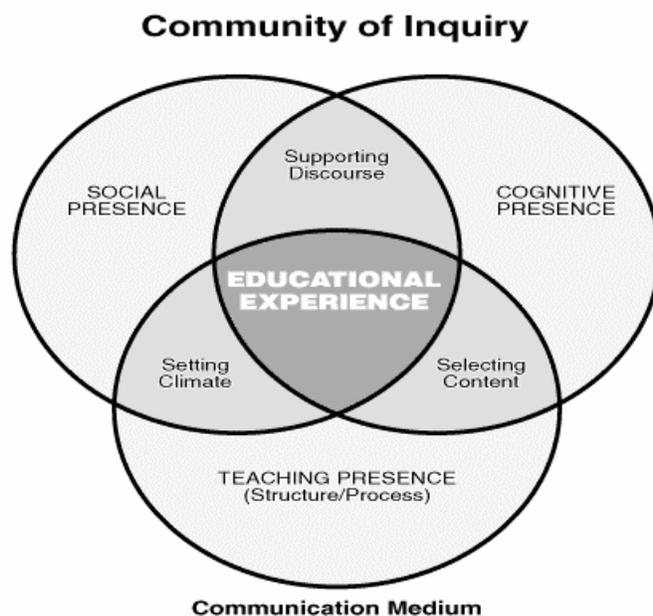
Figure 1. Community of Inquiry model

The educational experience resulting from the interaction of these three core elements is shared by both students and teachers. Garrison believes asynchronous learning networks have considerable potential for creating an educational community of inquiry (Garrison et al., 2000). The Community of Inquiry model in turn has been found

to be useful in analyzing and understanding interactions that occur within an asynchronous learning environment (Garrison & Cleveland–Innes, 2005).

The goal of true communities of inquiry is independent thinkers fostered by an inter-dependent collaborative community of inquiry (Garrison, 2003). Learners do not sit back and wait for the teacher to produce the information needed while students digest this information in any way possible. Members of a community of inquiry instead "question one another, demand reasons for their beliefs, and point out the consequences of each others ideas—thus creating a self-judging community where adequate levels of social, cognitive, and teaching presence are evident" (Garrison et al., 2001).

This community of inquiry in which teachers and students participate is constructivist in nature (Rourke et al., 1999). Garrison and Archer coined the phrase "collaborative constructivist" to describe their view of a worthwhile educational experience. Within this view, learners collaboratively communicate during their educational experience in order to construct knowledge. Garrison et al. (2001) view a community of inquiry as valuable if not essential in order for higher-order learning to occur, which is typically the goal of higher education institutions.

The phrase "community of inquiry" traces its origins back to philosopher Charles Sanders Peirce who was one of the first to connect the notions of community and inquiry together (Lipman, 1991). A community of inquiry was once seen as something only those participating in scientific inquiry could be part of, but was transformed to include others as well. A classroom community of inquiry in particular, is described by Lipman (1991) as one "in which students listen to one another with respect, build on one

another's ideas, challenge one another to supply reasons for otherwise unsupported opinions, assist each other in drawing inferences from what has been said, and seek to identify one another's assumptions" (Lipman, 1991). Lipman believed that implementation of the community of inquiry was possible in any discipline and would result in discussion and reflection about the subject matter and in doing so could promote higher order thinking. The focus in educational settings should be on deep understanding as Ramsden described (1988) where students build on previous ideas, connect concepts to everyday experience, and are concerned not just with the answer, but how to get the answer and what that answer means. The ideas of Lipman and Ramsden formed the basis for Garrison et al.'s Community of Inquiry model.

Social Presence

Social presence is defined as the ability of students to project themselves socially and emotionally in a community of inquiry (Rourke et al. 1999). Although the definition refers to students only, both learners and teachers produce social presence within a community of inquiry. "The purpose of social presence in an educational context is to create the conditions for inquiry and quality interaction to collaboratively achieve worthwhile educational goals" (Garrison & Arbaugh, 2007). Three categories of social presence exist: affective responses, interactive responses, and cohesive responses. Affective responses refer to the emotional expressions within computer conferencing such as use of emoticons, humor, and self-disclosure. Interactive responses include replying to posted messages, quoting directly from conference transcripts, and referring directly to the content of others' message postings. Cohesive responses build and sustain

the commitment of a group to the computer conference. Addressing participants by name

as well as referring to the group using inclusive words such as we, us, etc. add to the

cohesiveness of the group as do personal or trivial inquiries such as how someone is

doing, or commenting on the weather.

Teaching Presence

Teaching presence is defined as the design, facilitation, and direction of cognitive

and social processes for the purpose of realizing personally meaningful and educationally

worthwhile learning outcomes (Anderson et al., 2001). Garrison describes teaching

presence as "a means to an end" where social and cognitive presence is enhanced in order

to reach the educational goals set forth (Garrison et al., 2000). The three elements of

teaching presence are: design and administration, facilitating discourses, and direct

instruction. The design element refers to the curriculum materials, design of activities and

guidelines provided, timelines established, and modeling of appropriate use of the

conferencing medium. The facilitating discourses element aims to maintain students'

engagement in conferencing by prompting discussions, commenting on postings, and

reinforcing student contributions. Facilitation can be shared amongst students and

teachers. The direct instruction element looks to the teacher as the content expert and thus

as provider of intellectual leadership. The teacher is to focus and summarize the

discussion, and confirm understanding and diagnose misunderstanding found in the

postings.

A study by Arbaugh and Hwang (2005) assessed the construct validity of teaching

presence by administering a survey developed by Shea et al. (2003) in their study of

teaching presence to 190 graduate MBA students. Course design and administration, facilitating discourse, and direct instruction were each confirmed as distinct dimensions of teaching presence through factor analysis.

Cognitive Presence

Cognitive presence is defined as the extent to which participants are able to construct meaning through sustained communication (Garrison et al., 2000). "Cognitive presence reflects higher-order knowledge acquisition and application and is most associated with the literature and research related to critical thinking" (Garrison et al., 2001). Critical thinking involves both the process one goes through and the end product that results. The "process" of critical thinking is the focus of cognitive presence rather than the learning outcomes of individuals (Garrison et al., 2001). Kitchen & McDougall (1998-99) stated a need for an emphasis on the process of learning rather than the creation of a product for evaluation. By assessing critical discourse and reflection within an online learning community it is assumed that this process of critical thinking can be more readily facilitated (Garrison et al., 2001).

In order to operationalize cognitive presence for use in assessing online transcripts, Garrison et al. developed the Practical Inquiry Model shown in Figure 2, which is a generalized model of the critical thinking process based on the ideas of John Dewey. The Practical Inquiry Model recognizes that learning experiences include a student's personal world, where reflection and personal meaning takes place, and the shared world, where collaborative communication and shared meaning takes place.

Garrison (2003) believed that the way in which we combine and integrate these worlds

will make for an effective learning experience.
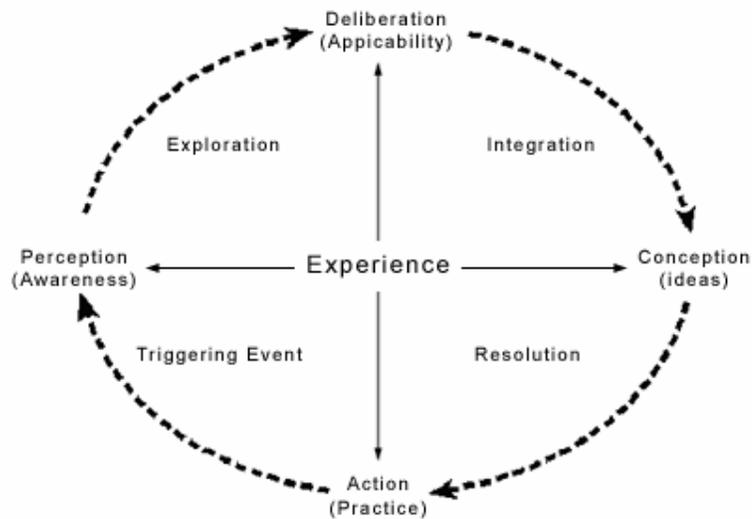
Figure 2. Practical Inquiry Model

The four phases that exist within the model are viewed as essential in describing

and understanding cognitive presence in an educational setting. The phases of the model

are: 1) triggering event, 2) exploration, 3) integration, and 4) resolution. The Triggering

Event is the beginning phase of critical inquiry and is typically represented by a task set

forth by the teacher in an educational setting. During the second phase, Exploration,

students brainstorm and try to pick out the important information needed in regard to the

task at hand. During the Integration phase, students apply and connect the ideas explored

in the Exploration phase in order to construct meaning. The last phase, Resolution,

involves a consensus building within the community and resolution of the task or

problem at hand.

Research on the Community of Inquiry Model

Computer mediated communication in an educational setting is believed to be capable of supporting social interactions between people (Rourke et al., 1999) thus making social presence in online communities a possibility. Studies have found that students feel an actual need for social interaction and bonding before being able to effectively participate in discussions (Bullen, 1998; Hara et al., 2000). Silver & Smith (1997) pointed out the need for mathematics students in particular to begin in a safe, possibly non-mathematical space, where they feel comfortable in developing a discourse community where mathematical ideas then become the norm.

High levels of learning are less dependent on the quantity of interactions and more dependent on the quality (Garrison & Cleveland-Innes, 2005). Increased learning does not necessarily result from an increase in the number of communication messages (Vonderwell, 2003), especially if the majority of messages are social in nature. Hara et al. (2000) found that interactions that are social in nature diminish over time within an online learning community while cognitive levels increase within the interactions. This implies that students become more task focused once they have formed a bond with one another. Social presence then becomes less visible as the focus of discussions shifts to that of academics (Garrison & Arbaugh, 2007).

The function of the social presence element of the Community of Inquiry model is to support cognitive and affective objectives of learning (Rourke et al., 1999). Cognitive goals are supported by the ability of social presence to initiate and support critical thinking while sustaining it over time (Rourke et al., 1999). Social presence is obviously

necessary but is also insufficient for creating a community of inquiry and encouraging

deep approaches to learning (Garrison & Cleveland-Innes, 2005). Appropriate teaching

presence is also needed to produce discussions with high levels of cognitive presence

(Garrison et al., 2000). Studies agree that if students are going to experience higher order

learning within an online community the discourse must be cohesive in nature from a

social aspect as well as structured from a teaching aspect (Aviv, 2003; Pawan et al., 2003;

Wu & Hiltz, 2004).

Teaching presence that is student-centered is believed to be the link in

transitioning students from purely social presence to cognitive presence (Garrison &

Cleveland-Innes, 2005) but there continues to be resistance to a more learner-centered

philosophy of teaching (Kitchen & McDougall, 1998-99). A study by Shea (2003)

showed teaching presence was correlated with student satisfaction and perceived

learning; however, when fellow classmates rather than the instructor were regarded as the

"teacher" in survey questions, correlations were significantly lower. One interpretation of

this result is that the students perceived the role of the instructor as central to teaching

and expected less from fellow students even though survey results indicated their peers

were engaging in the teaching presence behaviors. A study by Rourke and Anderson

(2001) on the other hand, found that students who worked in teams to lead online

discussions were not only able to fulfill the three roles indicative of teaching presence,

but were also preferred by their peers compared to the instructor-led discussions.

Students reported a satisfactory experience in the discussions and felt it contributed to

their learning. The perceived presence of instructors may be a more significant influence

on other student perceptions than perceived peer presence as was found by Swan (2003) in a study of social presence among instructors and students. Overt teacher facilitation is not always necessary to support cognitive presence (Arnold, 2006). Students are also capable of providing aspects of teaching presence deemed necessary for productive discussions. Yet the absence of overt instructor facilitation can sometimes contribute to a lack of dialogical discussions where ideas are challenged (Pawan et al., 2003).

Despite the uncertainness of the instructor's exact role, universities and colleges continue to move towards a collaborative student-centered environment for creating meaning (Ocker & Yaverbaum, 1999). Lecturing online or simply providing access to information is known to be a complete misuse of asynchronous learning networks (Garrison, 2003; Harasim, 2000) thus designs are needed that require instructors to be facilitators, rather than providers of information and correct answers, and to provide appropriate guidance. Instructors still influence the development of teaching presence in many ways without being authoritative. As the subject matter expert, relevant information should be interjected and misconceptions diagnosed (Garrison & Arbaugh, 2007; Wu, 2003) when deemed appropriate. Instructors are also encouraged to be more directive in assignments (Meyer, 2003, 2004; Wu, 2003). Both instructors and students are encouraged to push one another to justification, explanation, and meaning (Bullen, 1998; Meyer, 2003; Silver & Smith, 1997). Moderating, providing feedback, and modeling desirable behaviors for interaction are all strategies teachers could use in facilitating productive collaboration in an electronic environment (Wu, 2003).

Garrison (2003) claimed that in an asynchronous online learning context there are two properties, reflection and collaboration, that shape cognitive presence in ways unique to this medium. Because of this he argued that asynchronous online learning has a unique advantage over face-to-face learning in creating cognitive presence and achieving deep and meaningful learning outcomes through the integration of the these properties. Several studies have implemented Garrison's coding protocol for cognitive presence to assess the level of higher order learning that exists in varying online discussions (Arnold & Ducate, 2006; Meyer, 2003, 2004; Pawan et al., 2003; Schrire, 2006). Higher levels of cognitive presence were found in some studies (Arnold & Ducate, 2006; Schrire, 2006) while other studies found only minimal levels of higher order thinking (Meyer, 2003, 2004; Pawan et al., 2003). The research discussed previously on the properties of ALNs that support knowledge construction as well as the research on the inability of researchers to consistently find evidence of higher order learning in ALN discussions relates directly to the element of cognitive presence. The coding protocol for cognitive presence will be detailed further in the next chapter.

CHAPTER 3

METHODOLOGY

Introduction

The purpose of this study was to explore the existence of cognitive presence, the nature of online tasks, and the levels of cognitive presence generated by those tasks in an asynchronous discussion within the context of an online masters level course for mathematics teachers. A mixed method design (Creswell, 2002) was used to collect and analyze data about online tasks, online discussions, and student and instructor impressions of both. In mixed method research both quantitative and qualitative data is collected to explain and explore research questions. According to Creswell (2002) this form of mixed approach is based on triangulation, which compares multiple data sets to interpret whether they contradict or support one another. This chapter will review the methods of data collection and analysis included in the research design after first describing the population and context of the study.

MMTE Program, Courses, and Instructors

Data for the study was collected from an asynchronous online course offered as part of a program for mathematics teachers seeking a Masters of Science degree in mathematics education. The following descriptions of the program, the online courses it currently offers, and the instructors who design and deliver those courses provide a context for the study.

Masters Program in Mathematics
and Teacher Education (MMTE)

The program that provides data for this study results in a Master of Science

degree in mathematics for secondary teachers. It is offered by the Department of

Mathematical Sciences at a Research I land-grant university in the Rocky Mountain

region. Designed for high school or junior college teachers of mathematics, the MMTE (a

pseudonym) intends to deepen participants' understanding of school mathematics and

pedagogical content knowledge. The program promotes reflective and collaborative

approaches to teaching mathematics. The program originally started in the 1980s in a

face-to-face format where students were required to be on campus for eight weeks during

the summer. By 1996 enrollment in the program had declined so drastically that a

decision was made to shift the program to distance education mode. The MMTE program

in its new format was designed to serve teachers-in-service where they live and work;

therefore the majority of the coursework is completed off campus. At least two online

courses are offered each semester including summers. Class size averages 20 students,

most of whom are practicing teachers. Courses are offered via an asynchronous learning

network, allowing students to access their class at times during the day or night that are

most convenient to them.

MMTE Courses

Online courses in the MMTE program use WebCT, an online course delivery

platform commonly used in higher education, as the primary environment for course

discussion and interaction. Virtually all course activities are undertaken online through

asynchronous discussions based on readings, assignments, and posed problems. Although WebCT offers a variety of multimedia options, online courses in the MMTE program are generally text-based, without reliance on electronic features such as white boards, videos, cameras, or live chat. Eleven courses are currently offered online. Three courses have a distinctly pedagogical flavor, including courses in standards-based instruction, learning theory, and assessment. Four courses emphasize areas of content such as number theory, geometry, statistics, and discrete mathematics. The remaining courses, which mix content and other aspects of mathematical processes, address mathematical modeling, technology, mathematical language, and the history of mathematics.

MMTE Instructors

A core group of mathematics education faculty has consistently taught the majority of online MMTE courses since 2000 and thus has substantial and consistent experience in teaching graduate level MMTE classes online using the WebCT platform. Three adjuncts, two of them graduates of the program, have occasionally been hired to teach a course. The four professors as a group will be referred to as "the online instructors" for the remainder of this chapter. Each online instructor has a doctorate in mathematics education and has held a faculty mathematics education position in a mathematics department for between ten and twenty years. The design, development, and delivery of the MMTE online courses are a result of collaborative planning between the online instructors. All share a positive view regarding asynchronous learning networks and conduct their online courses in a similar fashion. Common to the online MMTE courses taught by these four professors are the following characteristics:

- A separate discussion is created for socialization and non-academic interaction within the WebCT course structure. The purpose of this addition is to reduce the amount of non-task based discussion postings in other areas, thus keeping the focus on academic tasks and discussions where appropriate.

- "Getting started" activities are implemented during the first week of instruction to allow students to get to know one another and become familiar with the course structure. The intent is to immediately engage the students and to form a cohesive group of learners who feel comfortable with one another, thus creating a sense of community. Introductory activities might take the form of asking students to describe their background and interests or tell a story from their teaching experiences in mathematics.

- In larger classes, groups of four to seven students are created by the instructor for purposes of discussion and collaboration. This increases accountability, encourages everyone's involvement in the group discussions, and for most students is a more comfortable setting. In whole class discussions consisting of 20 or more students, individuals can be easily overwhelmed by the sheer quantity of postings, or made to feel left out by more verbal classmates.

- Participation in discussions is given weight in determining the final course grade. The idea is to attach a sense of value to the online discussions where students are rewarded for their contributions. This may be as simple as giving points for posting a minimum number of messages, or it could be more extensive such as implementing a rubric for student self-assessment on the quality of postings.

- ▪ Discussions are student-centered rather than teacher-centered. The instructors view their role as facilitators of learning and focus and guide student thinking rather than funneling information to them (Wood, 1998). Instead of transmitting mathematical or pedagogical knowledge through direct instruction, the instructors pose challenges, ask questions, and create a context of student-centered inquiry.

Population

The population for this study consists of all students who have enrolled in one or more of the online courses offered by the MMTE program. This population is largely made up of students who are enrolled in the MMTE degree program—practicing mathematics teachers at the secondary or junior college level—but may also include graduate students from other programs, non-degree graduate students, and occasionally an undergraduate education major who has petitioned to take the course. Roughly two-thirds of the MMTE students are from the western United States, half of them in the home state of the university. The remaining students come from across the United States. Teachers in at least three foreign countries have also participated in the program.

Sample

The research sample consisted of 16 of the 17 students enrolled in a Fall 2007 online history of mathematics course (hereafter referred to as MATH 500). This class is a regular offering for MMTE students and was offered online for the second time in Fall 2007. This is a sample of convenience, as the availability of study subjects was limited to

those students enrolled in the MMTE course at the time of the study. Convenience sampling involves selection of the most accessible participants. Because of the timing of the study, students enrolled in a Fall 2007 online MMTE course were reasonable subjects.

The participants were evenly split between female and male students. One student was under 25 years of age, nine people were between the ages of 25 and 34, four were between the ages of 35 and 49, and two were over 50 years old. Only two students resided within 30 miles of the university, while twelve were from the western United States, one student was from the East Coast, and one student resided outside the continental United States. Only one person had not taken an online course using WebCT before taking the current course, and five had not taken, in particular, an online MMTE course previously. All students were graduate students in the MMTE program at the time of the study. The majority of the participants taught high school mathematics at the time of the study, while four taught middle school mathematics, one taught university level mathematics, one taught community college mathematics, and one was not teaching at the time. Seven students were beginning teachers with less than four years of mathematics teaching experience and five students had five to ten years of experience, while four had ten or more years of mathematics teaching experience. Overall this sample is representative of the general population in MMTE online classes.

Course Instructor

The online instructor for MATH 500, who will be referred to as Dr. Brook, has approximately 25 years of teaching experience in mathematics. His educational background includes bachelors and masters degrees in both mathematics and philosophy and a Ph.D. in Mathematics with a research specialization in Mathematics Education. Research interests of Dr. Brook include the use of technology in mathematics education and mathematics curriculum design. Dr. Brook joined the MMTE program faculty in 1988. His initial experiences with online learning occurred as a result of the program shifting to distance education mode starting in 1996.

Dr. Brook was one of the initial faculty members to develop an online course for the program. Besides guidance from an on-campus grant director involved with online course development, Dr. Brook claimed that "For the most part it was go in, look at the strengths and limitations of the setting for teaching, and basically look at the content you're teaching. Then design the types of experiences you're capable of designing in the environment. Needless to say it was learn as you go." External models and "how-to" manuals for online course design were not readily available a decade ago; rather, ideas were gathered from other people and design was entirely up to the instructor. Dr. Brook has taught many online courses in the years since; one of his colleagues estimates that he has taught at least a dozen online courses in the MMTE program. He had not previously taught the history of mathematics course (MATH 500) online, but he had taught it in a face-to-face format.

Dr. Brook designed all of the tasks for the online version of MATH 500, with the intent of selecting and creating tasks that promote high-level thinking. Since the tasks were of the instructor's own design, they were clearly representative of what the instructor normally assigns. Based on discussions with Dr. Brook and another MMTE faculty member, they were also typical of the types of tasks implemented by all MMTE instructors due to the collaborative nature of the online course design process. The only burden placed on the instructor by this study was a request to implement his assigned tasks on a schedule that provided a clear beginning and ending of each task, and in ways that reasonably isolated the related discussions for analysis purposes. These tasks were embedded in the Fall 2007 course and the resulting discussions were analyzed for evidence of cognitive presence and higher order thinking.

Design

This study investigated several research questions in the context of an asynchronous online graduate course for practicing mathematics teachers. Qualitative data analysis methods, content analysis, and descriptive statistics were used in an attempt to answer the following research questions:

1. Do the discussions generated in MATH 500 demonstrate evidence of higher level thinking in terms of cognitive presence?

2. What is the nature of the tasks that are implemented in MATH 500?

3. Is there evidence of a relationship between the tasks that are implemented in

MATH 500 and the levels of cognitive presence observed in the

corresponding discussions?

To answer these questions data was collected from a demographic questionnaire, a post-course survey, an instructor interview, and transcripts of the online discussions from MATH 500.

The original intent of this study was to implement each of several task types twice, once in the first half of the semester, and again during the second half of the semester in sequential order. The general characteristics of each MMTE task would not change from the first implementation to the second, and the corresponding discussions would be analyzed for growth in cognitive presence. Table 1 shows the proposed schedule for this implementation.

Table 1

Task placement schedule

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task			1A		2A		3A		1B		2B		3B		

However, the nature of the course, the students, and the instructor, and the natural progression of events that occurred as the course unfolded confounded this plan. The researcher determined that it would be too constraining, with potentially damaging effects on the discussions, to expect the instructor to implement specific tasks on a prescribed timeline. As it turned out, several task types were indeed implemented more than once,

but not in a sequential order as shown in Table 1. The timing and sequence of task

assignments could no longer be used to determine which discussions to analyze. Instead,

the researcher decided to undertake analysis of every message in the course discussions.

All course tasks were categorized, and their corresponding discussion postings analyzed

for evidence of cognitive presence.

<u>Instruments and Data Collection</u>

A researcher-developed questionnaire (see Appendix A) was used to collect

demographic information from the participants in the study including age, gender, and

residence along with background information such as previous education, online

experience, teaching experience, and extent of mathematical content background. The

questionnaire was sent to participants as an attachment within the WebCT email system.

A consent form in PDF format was also sent for students to sign and return, with the

researcher's signature already in place so that students could keep their own copy. The

questionnaire consisted of Likert scale questions and required approximately 30 minutes

for completion. Students were asked to return both documents via email or postal mail.

Because of the difficulty students encountered in both downloading the PDF file and

determining how to scan it for return, they were given approximately three weeks to

complete and return both the questionnaire and the consent form. Only one student did

not return the consent form and questionnaire, thus signifying her choice to not

participate in the study.

A post-course survey (see Appendix B) was developed to assess student

perceptions of tasks implemented in the course. The researcher designed a series of open-

ended response questions based on the coding protocol used to assess cognitive presence

in the discussion transcripts. This part of the survey was piloted with 11 students enrolled

in a Summer 2007 online MMTE class to determine if respondents were able to

understand the questions being asked and to develop construct validity for the survey.

The intent was to design an instrument capable of obtaining information from the

students' perspective that could be triangulated with the information obtained from the

coding protocol. Surveys were sent via WebCT by the instructor of the course and

students were asked to email or mail via standard mail their responses directly to the

researcher within two weeks. The instructor offered extra credit for completion of the

survey. Eleven students returned the survey. Upon analyzing the responses to each

question on the survey, changes were made to adjust for student confusion in terms of

question wording and to obtain more relevant information in terms of the research

objectives.

The Community of Inquiry Survey Instrument (Garrison et al., 2007) comprised

the second half of the post-course survey. The survey consists of 34 statements about the

three elements of the Community of Inquiry model. The questions were answered on a

five-point Likert scale. The researcher attended the 13th Sloan-C Conference on

Asynchronous Learning Networks in November 2007 and attended a presentation where

the Community of Inquiry Survey Instrument was discussed by the instrument

developers. Dr. Peter Shea emailed a copy of the survey to the researcher for use in the

present study. The survey was used to ascertain student perceptions of all elements of the Community of Inquiry model.

The revised survey was emailed to students in MATH 500 during the first week of January 2008, after the coursework was completed and grades were assigned. Students were told a hard copy would be mailed to them via standard mail upon request, which none requested. Students were asked to return the survey via email or standard mail to the researcher and were initially not given a deadline for completion of the survey. After twelve days five surveys were returned, four via email and one via standard mail. The survey was emailed a second time to the remainder of the students explaining that their reflections on the course would fade as they started a new semester, thus a requested deadline was given of one week. During that week five more surveys were returned via email. An email was sent to the remaining non-responsive students after the one week deadline as a final reminder for surveys to be turned in. Three more surveys were returned for a total of thirteen post-course surveys.

As part of the survey, students were asked to provide contact information (home address, phone number, and/or email address) on a voluntary basis if they were willing to participate in a follow-up interview at a later time. Three students provided all of their contact information and one student provided an email address. Any follow-up interviews would be used to clarify survey questions and also to pursue any themes that emerged from the responses to the survey questions. No student interviews were conducted in the study.

A lengthy interview was conducted with the course instructor, Dr. Brook, on December 5th of 2007. The interview was semi-structured and took place in Dr. Brook's office. The interview was taped upon receiving permission from Dr. Brook to do so and notes were taken by the researcher during the interview. The interview lasted approximately 2.5 hours; after approximately two hours the tape ran out without being noticed. Thus the majority of the interview was transcribed verbatim to a Word document, while the remainder of the interview was transcribed from the notes taken by the researcher. Dr. Brook was asked a series of questions pertaining to his background as a mathematics educator, the MMTE program, his beliefs about online learning, his preferred online tasks and teaching strategies, and his impressions of MATH 500 and another online course he taught in Spring 2007. The instructor's responses were used to build an accurate description of his background and of the MMTE program, and also to ascertain his views on various aspects of teaching and learning in the online medium. Dr. Brook was also asked for his perspectives on higher order learning and critical thinking. A copy of the interview protocol can be found in Appendix C.

The researcher received permission from Dr. Brook to access the full electronic record of MATH 500 in the WebCT archives. Transcripts of the online discussions corresponding to MATH 500 were archived for later analysis to determine the level of cognitive presence attained within each discussion. WebCT allows for easy back-up of the entire course to the university server or a computer desktop where it can be copied and transferred or uploaded to other computers. Descriptions of the process and

instrument used for content analysis form a substantial portion of the discussion in the following section.

Data Analysis Techniques

Demographic data were transferred to an Excel spreadsheet for analysis and were used to provide an overall demographic snapshot of the participants. The data were analyzed by the researcher to reveal any heterogeneous traits of the sample. Participants who were deemed as outliers were noted so that discussions including these persons could be further investigated should the researcher observe any discrepancies during transcript analysis. Students D, L, and Q were noted as outliers due to the lack of mathematical preparation found in their educational backgrounds when compared to the rest of the class. Students D and L had earned math minors, while student Q had earned a degree in an area in the sciences which would have required some mathematical preparation in earning the degree. Student M was also noted as an outlier for being the only student who had not taken an online course using the WebCT platform before taking the MATH 500 course. This included not having previously taken any MMTE online course. In contrast, students A, F, Q, and K had taken an online course using the WebCT platform previously, but had not taken an online MMTE course in particular. Three students, D, G, and P, were teaching at the college level during the time of the study, while the rest of the class was teaching either middle school or high school mathematics.

The returned post-course surveys were saved in Microsoft Word format in two ways: 1) each survey was saved individually according to the person who completed the

survey, resulting in 13 saved individual post-course surveys, and 2) all responses

corresponding to each individual question were copied to a single Microsoft Word

document, grouping the responses for each survey question posed and labeling each

response according to its author. The thirteen individual surveys were read holistically to

examine whether a student's perceptions were influenced by his or her demographic

background. The grouped responses to each individual question were also read

holistically to ascertain the common themes that existed (if any) for the entire class.

Responses for each question were then grouped according to the task they referred to

rather than by student. The responses pertaining to each task were analyzed for

similarities in the comments about each task. An overall picture of student perceptions of

the tasks was eventually compared against the instructor's perceptions as well as the data

collected through content analysis of the online transcripts.

<p align="center">Content Analysis of Discussion Transcripts</p>

All discussion transcripts from the Fall 2007 course were analyzed using content

analysis techniques. The content analysis coding protocol used for this study was

developed by Garrison et al. (2001) to specifically assess cognitive presence (See

Appendix D). Garrison et al. define cognitive presence as "the extent to which learners

are able to construct and confirm meaning through sustained reflection and discourse in a

critical community of inquiry" (2001, p. 5) and state that cognitive presence reflects

"higher-order knowledge acquisition and application" (p.6). They believe the model is

appropriate in adult, continuing, and higher education where applied knowledge is

valued. Although other content analysis instruments exist (see Chapter 2), the parameters of this study make the cognitive presence coding protocol the most appropriate choice.

Content analysis is commonly referred to as a quantitative research method that is used to code and analyze text. Simply put, content analysis typically involves choosing a coding scheme consistent with the study objectives, choosing a unit of analysis, training coders to use the protocol, assigning each unit to a category of the coding scheme, checking for reliability of the coding decisions, and calculating frequencies for each category. Garrison, Cleveland-Innes, Koole, and Kappelman (2006) refer to the application of the Community of Inquiry framework and its associated coding protocol as a qualitative approach. They state that "the coding of the transcripts remains a qualitative analysis, even though the frequencies are provided to help gain a quantitative sense of what is occurring" (p. 4). Although the researcher assigned numeric codes to the transcript data, these codes represented qualitative categories based on indicators of cognitive presence. That data was used both to report descriptive results and to draw conclusions from a qualitative perspective.

Identifying segments of transcripts that will be coded is called unitizing (Rourke et al., 2000). The goal is to select a unit that multiple coders can reliably identify. In this study, the unit of analysis used for coding was a complete message which corresponds to one person's individual posting. Garrison et al. (2001) stated that because of the clarity of identifying a message within a transcript, coders can reliably choose the unit for coding decisions and thus improve the reliability and validity of the study. It also produces a manageable set of units to be coded whereas a sentence, word, or paragraph unit would

require an extensive set of coding decisions (Rourke et al., 2000). Messages that had

multiple levels of the coding scheme present were "coded up" to the higher level

represented within the message. This is consistent with Garrison et al. (2001) who claim

that the code-up procedure is justified since higher levels of critical thinking borrow from

the previous levels.

<center>Preparing to Use the Protocol</center>

Training for use of the cognitive presence coding protocol was an exhaustive and

extensive process. Initially, the researcher and a mathematics education professor (not Dr.

Brook) experienced in using content analysis for the coding of online discussion

transcripts carefully examined the cognitive presence coding protocol. Over several

sessions, they reached a comprehensive and mutual understanding of the protocol.

Descriptions of each phase of the coding protocol were related to the indicators and

socio-cognitive processes within each phase so that both coders understood the various

components. The coders then proceeded to use the coding protocol to analyze 40

messages from a Spring 2007 online class that is part of the MMTE program and nine

messages from the Fall 2007 online course, MATH 500. The messages coded from the

spring course were based on discussions of a pedagogical nature, while the nine messages

coded from MATH 500 were about a mathematics problem.

Together the coders read through a single message and then read through each

indicator of the coding protocol to analyze whether or not each indicator applied to the

message and how. They then agreed on which indicators were present and on the overall

highest phase achieved in the message. For instance, if a single message contained both

Exploration indicators and Integration indicators the message was coded as Integration.

An idea raised was to code each message with every indicator observed within the

message, but this approach was set aside because the researcher believed this negated the

idea of using a single message as the unit of analysis. The coders agreed that the phase of

each message would be used in data analysis rather than both phase and indicator.

However, it was decided that the indicator most prevalent within the message would be

recorded in order to indicate each coder's reason for choosing a certain phase, thus aiding

in reliability of coding decisions.

During the training process an education professor located on the university

campus who is experienced in using the cognitive presence coding protocol in his own

research was also consulted for advice on use of the cognitive presence coding protocol.

Because the context of his recent research was a statistics class, similarities were believed

to exist with this researcher's use of the protocol in the analyzing transcripts. The

researcher, the second coder, and the education professor met twice to discuss

interpretations of the four phases of the cognitive presence coding protocol. Sample

messages were shown to the education professor for his opinions on the coding of the

messages.

Over the course of several weeks each coder proceeded to independently code

messages from each class. These included 30 messages from the Spring 2007 online

MMTE course (also taught by Dr. Brook) as well as 54 messages from MATH 500. Once

coding of a collection of messages was complete, the coders would compare results and

discuss any discrepancies in coding until agreement was reached or until the coders agreed to disagree. This system is often referred to as a "negotiated approach" to coding. Garrison et al. (2006) stated this approach "provides a means of hands-on training, coding scheme refinement, and thereby, may increase reliability" (p. 3). The coders would then code another grouping of messages and go through the negotiated coding process once again. This cycle was repeated until agreement on a final modified protocol was reached.

The two coders discussed the cognitive presence coding protocol indicators, their application in the context of the MATH 500 discussions, and whether or not to refine the coding protocol. Use of the cognitive presence coding protocol had never been reported in the context of a graduate mathematics course populated by practicing teachers. It became apparent that additional categories were needed in order to accurately analyze every message in the transcripts. The coders considered the addition of a category referred to as "Comments" which included messages not related to cognitive presence and an Exploration indicator called "Questioning" which included messages where students were requesting specific information from others.

In order to gain a better understanding of the coding protocol the researcher emailed Dr. Garrison, one of the originators of the COI model, and more specifically the cognitive presence coding protocol. Nine questions pertaining to the various coding dilemmas encountered by the coders were presented to Dr. Garrison for his expert opinion. Dr. Garrison immediately responded to each question and stated "my overall response I have is to decide why you have coded in a certain way and stay with it. At this

stage of the methodology, it is largely good, consistent judgment." Based on Dr.

Garrison's responses, the coders felt comfortable modifying the cognitive presence

coding protocol as described above.

<u>Applying the Protocol to MATH 500 Discussion Transcripts</u>

Once the coders completely agreed on all interpretations of the coding protocol,

the researcher became the sole coder of the main study transcripts. While coding, if the

researcher felt that certain messages did not clearly fit into one phase, they were noted

and later sent to the second coder for her opinion of the message. In most cases both

coders agreed on the coding. If differences remained after discussion, they were noted in

the Microsoft Excel spreadsheet. Message sequences from a variety of course discussions

were also coded by the second coder in order to provide a check that the researcher was

consistently using the coding protocol in the manner agreed to by both coders. Overall

976 messages were coded by the researcher and 62 were checked by the second coder.

All messages pertaining to the assignments from the Fall 2007 MATH 500 course

were coded, including re-coding of any messages that were previously used for training

purposes since the coding protocol and the coders' understanding of the protocol had

evolved over time. The researcher first printed transcripts of each discussion by

compiling the messages associated with each individual task and individually printing

them. Task instructions were printed, and individual assignments were identified.

Instructions for each assignment and its corresponding discussion threads were kept

together for analysis purposes. Coding decisions that included the phase and most

prevalent indicator were recorded in a Microsoft Excel spreadsheet. As stated previously,

the indicator was simply to aid in the negotiation and confirmation of coding decisions.

Also recorded for each message were the message number, initials of the person who

posted the message, and any comments about the message the researcher wanted to note

for later reference.

While coding individually, the researcher came to realize that many postings

appeared to be the product of specific assignment instructions. These postings did not

emerge out of student discussion, but rather as a result of assignment requirements. For

instance, in assignment 13 Dr. Brook stated "I want you to solve the problem and submit

your solution to the group folder" which indicates that students were to solve the problem

individually and post their answers. The researcher, upon agreement with the second

coder, coded these postings in the Exploration phase but made note of their unique status

by indicating that they were "required postings" (RP). The researcher also decided to

code nearly all messages posted by the instructor in a special category titled "teacher

presence" (TP) since they provided elements of teaching presence. Since teaching

presence was not a focus of this study the teacher presence messages were noted but then

omitted from content analysis.

<div align="center">Validity and Reliability</div>

Validity

Correlational analysis was used in the present study to establish validity. In this

type of study measurements of a construct using content analysis are compared to

measurements of the content through other methods (Rourke & Anderson, 2004). The validity of the cognitive presence coding protocol was established by also surveying students through both researcher developed questions and the Community of Inquiry Survey Instrument designed by Garrison, Shea, Swan, Arbaugh, Ice, and Richardson (2007). Data from each method was triangulated which is viewed as one of the important strategies that can be used to ensure internal validity (Stake, 1995 as cited in Schrire, 2006).

Construct validity refers to the degree to which inferences can legitimately be made from the operationalizations in a study to the theoretical constructs on which those operationalizations were based. The theoretical constructs of cognitive, social, and teaching presence that make up the Community of Inquiry model were explored and validated in studies by Garrison, Cleveland-Innes, & Fung (2004) and Arbaugh (2007).

The frequency data that resulted from coding of the data were used to describe the level of cognitive presence that was present in the coded discussions. The validity of the descriptions depends largely on four criteria discussed by Rourke, Garrison, Anderson, and Archer (2000): objectivity, reliability, replicability, and systematic coherence. Replicability refers to the ability of multiple groups of researchers to apply a coding scheme reliably. The lack of replicable studies is regarded as a serious problem; reliable application of schemes by researchers who are not involved in creating them would help in proving their efficacy (Rourke et al., 2000). Systematic coherence, while not explicitly defined by the authors, suggests that findings are coherent both internally and within the larger body of research literature. Reliability is discussed at length in the next section.

<u>Reliability</u>

"The primary test of objectivity in content studies is inter-rater reliability, defined as the extent to which different coders, each coding the same content, come to the same coding decisions" (Rourke et al., 2000). Two common measures of inter-rater reliability are Holsti's coefficient of reliability (CR) and Cohen's kappa (k). The CR is a percent agreement statistic reflecting the number of agreements between the coders divided by the total number of coding decisions. Cohen's kappa reports inter-rater reliability after accounting for chance agreement between the coders and is viewed as a more conservative statistic. Normative values of each statistic have not been established but a minimal level of 70 - 80% is typically accepted for percent agreement figures (Rourke et al., 2000).

In one study, Garrison et al. (2000) used their original coding scheme to code three transcripts. The first two codings were used to refine the scheme and resulting inter-rater reliability statistics for the final coding were found to be CR = .84 and k = .74. Content analysts suggest researchers must decide for themselves the acceptable level of agreement (Rourke et al., 2000). The percent agreement statistic calculated for the present study was CR = 92%, and the Cohen's kappa calculated for this study was k = 87%. Although the number of messages coded by both researchers was admittedly small, their frequent discussions and eventual agreement regarding "borderline" messages contributed to the reliability of the coding process.

The coding protocol for cognitive presence has been used in a variety of studies. Both Meyer (2003, 2004) and Schrire (2004) successfully implemented the coding

protocol, but neither reported inter-rater reliability statistics for the studies they conducted. Pawan et al. (2003) reported an inter-rater reliability percent agreement of 89% using the coding protocol unchanged, and then reported a percent agreement of 94% after refining subcategories of one phase of the model due to the unit of analysis the researchers chose. Arnold & Ducate (2006) established an inter-rater reliability percentage of 86% when coding transcripts using the Garrison et al. framework (2001) for cognitive presence while Vaughn's (2004) implementation of the cognitive presence coding protocol resulted in reliability figures of CR = .86 and k = .84. McKlin, Harmon, Evins, & Jones (2001) used neural network software to develop a way to categorize text from transcripts into categories of the cognitive presence coding protocol. Text coded manually was compared against text coded by the software program to compute reliability figures of CR = .84 and k =.76.

Every successful application of the cognitive presence coding protocol contributes to its validity. However, normative data for the protocol is difficult to generate since many studies (including this one) modify the protocol in one or more ways.

A listing of limitations and delimitations concludes the discussion of research methodologies used in this study. The following chapter presents a detailed account of the results of content analysis and other data analysis procedures.

Delimitations and Limitations

Delimitations

- The participants in this study included only those students enrolled in one MMTE class in Fall 2007.

- Only one of the MMTE online instructors participated directly in this study as a course instructor.

Limitations

- The levels of cognitive presence identified in the MMTE discussions may have been affected by the two other components of the Community of Inquiry model, teaching presence and social presence, which were not controlled in the study.

- The course instructor had ultimate control over the pace of the course and the assignment of MMTE tasks and other work. Some discussions may have been cut short and not given enough time to evolve, or students may have been overloaded with work resulting in lack of time to use the discussions effectively.

- Normative standards do not exist for the content analysis coding protocol.

- Content analysis itself is found to be methodologically challenging in terms of reliability and validity.

CHAPTER 4

RESULTS

Introduction

This chapter presents results from the data analysis techniques that were used to address the research questions for this study. A descriptive overview of the messages posted in MATH 500 is presented in the first section. This is followed by a thorough overview of representative examples of messages coded to each category of the cognitive presence coding protocol. A holistic summary of the number and percentage of messages coded to each category concludes the section. In the next section cognitive presence among individual students is discussed in terms of the proportion of messages coded to each phase of the Practical Inquiry Model. In particular, the students with the highest and lowest number of Integration postings are analyzed for similar traits. In the final sections, discussion messages are divided into assignments for analysis. Instructor and student perceptions of the task types encountered in MATH 500 are discussed and then the assignments are analyzed in terms of those task types.

Overview of Course Messages

A total of 1,111 messages were posted in the discussion areas of MATH 500. Of those, a total of 976 messages were analyzed for this study. The remaining 135 postings were not included as they clearly served an administrative or social purpose. Non-discussion postings included 54 messages in the "Assignments" folder and 16 student-

posted "Book Reports." Another 34 messages were in the "Introductions" folder where

students provided autobiographical information and purely social comments. The

remaining few were either posted in error or not relevant to the course and its material.

The 976 messages analyzed for the study included discussion postings by the

instructor and by the seventeen students registered for the class. The fewest number of

postings by an individual student was 17. This person dropped out of the class mid-

semester. The messages posted by this student were still included in the study, as they

were woven into the group discussions. Excluding this drop-out, the number of total

postings per student ranged from 23 to 92 messages. The average number of postings per

student was 55.5, with a median number of postings of 57.5. The instructor posted a total

of 71 messages. The instructor did not have a quantitative requirement of the students for

participation in the online discussions (for example, a weekly minimum number of

postings per student). Instead, in the course syllabus the instructor stated "By the very

nature of the course, constructive participation in discussions is a requirement."

<u>Coding Protocol and Adaptations</u>

The cognitive presence content analysis coding protocol developed by Garrison et

al. (2001) served as the basis for coding the online mathematical discussions of teachers

in MATH 500. As described previously in Chapter 3, the unit of analysis was an entire

message. Each message was coded into one of six categories. The first four—Triggering

Event (TE), Exploration (EX), Integration (IN), and Resolution (RE)—correspond to the

four phases of the Practical Inquiry Model (PIM) which correlate to cognitive presence.

The remaining two—Comments (CO) and Teacher Presence (TP)—were added to

account for messages that did not represent cognitive activity by the students. Examples

of postings that were coded into each category are presented in the sections that follow.

(Note: spelling errors have been corrected in words shown in brackets.)

Comments and Teacher Presence

As described in Chapter 3, the category "Comments" was added to account for

requests for help, supportive comments, and other conversational elements that did not fit

reliably into the PIM model.   In some cases, a student such as this one was having a

technical problem:

> Message 114
> Help!!!! For some reason I can't login into the library e-reserves! This is the first
> time this has happened to me and I need to call the library services and find out
> what's up! Could someone please send me an e-mail with the article attached?
> Thanks in advance!

In other cases, a student might give a "pat on the back" to another student without adding

to the depth or content of the discussion:

> Message 46
> I read your summary, nice job on catching the main points of [Jones'] first
> chapter.

Overall, 88 postings were coded as Comments. To reiterate, these postings are considered

non-cognitive in nature.

The Teacher Presence category was used to categorize nearly all postings by the

instructor. The purpose of this study was to examine the levels of cognitive presence

among the students, thus the instructor postings were not coded to the phases of the

Practical Inquiry Model. In addition, the "teaching presence" and "social presence"

components of the Community of Inquiry Model were not analyzed in this study.

Of course, the quantity and quality of instructor postings certainly had an effect

on the cognitive presence of the students. The instructor's postings varied from providing

basic information to stimulating deeper thought about an assigned problem. In this

example of teaching presence, the instructor is simply setting up the root of a message

thread for the students:

> Message 52
> Hi everyone:
> I thought in the interest of organization that you would use this message [as] the place to post our work on the Dido problem. Just post your ideas as [replies] to this message and you will create a threaded discussion that is easy to separate from the discussion going on about the readings for unit one.

Another example shows the instructor clarifying a mathematical misunderstanding and

also guiding the students to look to another student for help:

> Message 205
> Following my hint only helps with proving that the maximal quadrilateral must have sides of equal length, i.e. it is a rhombus. It does not prove that the rhombus must be a square. So you have a bit more to do. Student H is onto something.

In the following example, Dr. Brook re-focuses the class when they wander off track

from the original task:

> Message 397
> I want to clarify-----The only method I want you to analyze is the student method of trisecting a segment AC and using its trisection points to trisect angle ABC. Millions of methods have been tried in the history of mathematics. But the question is, does this student method ever work and if so when? Of course I want you to prove your answer.

In this last example, the instructor provides guidance to a student who stated that "There

must be something wrong in my work but I can't seem to find it."

Message 419
Your proof assumes the method works and uses the resulting information to place bounds on the size of the angle that will work. By digging deeper you will be able to find more restrictive bounds, i.e. no value of x will work. So there is nothing wrong with your logic up to this point.

Overall 71 messages were posted by Dr. Brook. Sixty-six were coded as teacher presence; the remaining five were coded as comments or exploration. Teaching presence can be displayed by any participant of an online discussion, not just the instructor. For the purposes of this study instructor postings were referred to as teacher presence. This was justified by the fact that cognitive presence was the only aspect of the Community of Inquiry model under investigation. Technically, all messages could also be coded according to the coding protocols for social presence and teaching presence, but that would go beyond the scope of the present study.

The Practical Inquiry Model

Although messages were also coded as Comments and Teacher Presence, the four phases of the Practical Inquiry Model were the categories of greatest interest in this study. Overall 826 messages were coded into the four phases of Triggering Events, Exploration, Integration, and Resolution.

Triggering Events: Triggering events are messages that take the discussion in a new direction or messages expressing confusion in understanding the initial triggering event. Only six student messages were coded in this category. Triggering events were used by the instructor to launch a discussion. However, the instructor typically posted the triggers within the assignment folder of the course in the form of instructions. The

instructor often presented background and guidelines for a learning task, then directed

students to post and participate in a discussion. The following excerpt is an example of a

triggering event presented by the instructor in the assignment folder:

> Message 332
> One of the classic problems of geometry was the challenge of finding a construction method, using straightedge and compass, for trisecting any angle. It is not hard to trisect some angle like right angles, but the problem was to come up with a general construction method that works for all angles. A popular method thought of by many student is the following. Given angle ABC. Draw segment AC and use the standard construction method for dividing AC into three equal segments, AE, EF, and FC where E and F are points between A and C. Now draw rays BE and BF and, voila, you have trisected angle ABC. Ok…..I want you to explore whether this method ever works and, if it works sometimes, determine when it works.
> I am posting a message in each group folder for you to respond to so that your discussion of this problem stays in one threaded message area.
> Start responding immediately.

In general, students did not post triggers that raised new questions or took the

discussions in an entirely new direction. They asked questions, but these were most often

advancing the same topic in various ways, thus not providing a true trigger. On a few

occasions, triggers were sometimes present, but the practice of "coding up" resulted in a

trigger not being represented in the coding due to a higher phase being observed. The

example of a triggering event that follows shows a student struggling with the instructor's

initial trigger:

> Message 65
> I guess my question is where to start. Can the polygon be the same kind [but] just have different side lengths? I guess what I am asking is can all the polygons be a pentagon with the same perimeter just different side lengths. Or are we going to use a quadrilateral, pentagon, hexagon as long as they have the same perimeter? I think I will start with a table. Talk to you all later.

Exploration: Exploration is the second phase of the Practical Inquiry Model. Students in this phase share and compare information with one another relating to the Triggering Event. Brainstorming, suggestions for consideration, and information exchange are a few of the indicators found in the postings associated with this phase. Six hundred thirty seven of the 826 messages coded into the four phases of the PIM were coded in the Exploration phase. In other words, of all discussion postings in MATH 500 that applied to the Practical Inquiry Model, over 75% of those messages were attributed to the Exploration phase. The following examples demonstrate several different forms of Exploration, which comes with a variety of indicators in the coding protocol. In the first example, a student acknowledges a peer's approach to a mathematics problem and then suggests his or her own approaches to the problem:

> Message 122
> Sounds like a good place to start.
> I messed around with this problem some and had two other possible approaches. One was to assume [that] a circle maximizes area, and then show that regular polygons, approach the shape of a circle as n goes to infinity. We'd need to fill in more details, but it seems a possible strategy.
> The second idea was to prove this for the first few regular polygons, such as an equilateral triangle and a square and then build an inductive type proof.
> I will spend some considerable time on this problem this afternoon and post again this evening. I apologize for not being a better participant, I was busy for the holiday, and we just won't even talk about yesterday…☹

Note that the student does not build upon the "good place to start" suggested by a previous student, which would indicate integration of ideas. Instead, the student shares his or her own ideas in a brainstorming approach, causing the message to be coded as Exploration.

Another example of a message coded as Exploration is a posting where the

student shared information he or she had just discovered with the other students:

> Message 187
> Looking for a way to prove the equiangular aspect of the Problem of Dido, I came across this formula for the area of a quadrilateral. It is most excellent!
> In case you don't know it (I'd never seen it before), it looks similar to Heron's Formula, but for quadrilaterals. This is definitely a keeper.

Although the student did not directly share the formula here (it was posted later, after the

instructor asked the individual to share it) the intent of the message was to provide

information the individual found with the other students in the class. This reinforces the

notion that the Exploration phase is that of sharing and exchanging information.

The cognitive presence coding protocol and its indicators were not a perfect

match for the task of coding MATH 500. At least one indicator for Exploration,

"Unsubstantiated contradiction of previous ideas," was never found among the course

messages. Similarly, a few indicators had to be added to account for specific message

types. As noted in Chapter 3, one indicator that was added to the Exploration phase was

"Request for information," shown in the following example.

> Message 1025
> I am not understanding—which vertex did you put in the center?

> Message 1026
> Sorry about that, I should have said center of the circle. I used it for the vertex of the 360/n degree angles.

The student in message 1025 is asking for information to help clarify his or her

understanding. Often the information is supplied by another student or by the instructor.

In this case, the student in message 1026 provides the requested information without

continuing on to extend the exploration. Both messages were coded under the

"Information request" indicator.

Another example of a student requesting information follows:

Message 610
I didn't even think of time in terms of base 60!
When I was growing up, in junior high math we worked quite a bit on different base systems (not connected to any modular math) – converting numbers back and forth from different bases. I don't think the middle school math even broaches those topics anymore—does anyone teach different bases in schools below the college level?

In this example, the information request is mingled with an exchange of information

based on personal narrative—another Exploration indicator. This student is asking for

information from other students, not to complete a course-related problem or to

understand someone else's work, but instead to expand his or her knowledge of the

mathematics curriculums in today's schools. A student responded to this request based on

personal knowledge in the following way:

Message 611
I have not heard of anyone teaching different bases in grade school. The only class I know that uses them much is Math for Elementary Teachers at the college level and you see modular arithmetic in classes such as number theory, cryptology, or knot theory.
I know in the Math for Elementary Teachers, students typically find using alternate base systems very confusing. I'm not sure how it would go over at a middle school or high school level.

Message 611 is providing information in response to the previous student's request. Had

the student not made the original request for more information, this posting would have

likely not occurred. Thus, the indicator "Request for information" was used often, and

many times in paired messages.

Integration: The third phase of the Practical Inquiry Model is Integration. In this phase students make connections between the ideas that are shared in the Exploration phase and create a synthesis of new understandings. By building upon others' ideas, presenting justified yet tentative hypotheses, and integrating information from various sources, students are able to converge upon a common conclusion or result. In this phase indicators reveal that discussion participants are constructing new meanings rather than sharing information, thus this phase represents higher-order learning. Of the 826 messages coded using the Practical Inquiry Model phases, 155 were coded as Integration. The researcher coded over half of these messages based on the indicator "Convergence among group members" which can be described as building onto others' ideas and expressing substantiated agreement. The following series of messages gives an example of the discussion moving from Exploration to Integration and back to Exploration. The first message was coded as Exploration; there is a suggestion of a starting point.

Message 69
Student A: Should we start by establishing the fact that our maximal polygon must be convex?

Message 71
Student B: I hadn't even considered non-convex polygons, but yes, that sounds good. Then I really think the way to pursue this is to establish that for a given perimeter, an equilateral triangle (composed of 3 isosceles triangles) gives the maximum area. I think the isosceles triangles that make up that equilateral triangle are essential—we can decompose any n-gon into n triangles—if decomposition into congruent isosceles triangles gives us maximum area for given perimeter, then regular n-gons give max area for given perimeter.
I have tried to find a way to link area and perimeter into an equation that we could use calculus with to find a maximum, so far without success. Any thoughts that way?

The author of Message 71 acknowledges the previous message and agrees to approach

the problem in the way suggested. Had the individual simply said "I agree, let's do that"

without anything further, the message would have been coded as Exploration rather than

Integration because the individual did not advance the idea. But as the posting continues,

the individual builds on the original idea by saying how to proceed further with the

problem. He then poses his own question, reverting to Exploration under the indicator

"Suggestions for consideration." The dialogue continues:

> Message 73
> Student A: I think calculus could be a powerful tool for finding a maximum, but
> I've had no luck writing a global equation to differentiate.
> Going back to the isosceles triangle idea: we know this is correct. But how do we
> demonstrate it?
> I think it will be straightforward to show that, for a triangle of perimeter P with
> one side of length L, the maximum area will be enclosed when the lengths of the
> other two sides are equal (isosceles). From there we must leverage this principle
> up to apply to an arbitrary n-gon.
> I say it's straightforward, but I haven't done it yet! I'm still trying to think big
> picture…

In the response above, Student A acknowledges the question set forth at the end of the

previous posting and then goes on to build upon the other ideas presented, thus the

message was coded at the Integration phase. Notice that this student poses a rhetorical

question, which he then goes on to answer for himself.

> Message 74
> Student B: How do we show that for a given base, the max area triangle exists
> when the two remaining sides are equal? Is it because the two equal sides will
> give us the most height as they intersect?

In this final posting of the series, Student B reverts back to the Exploration phase by

stating questions of uncertainty and asking for opinions from the other student to verify

his or her line of thinking.

The series of postings shown above gives an example of the need for "good, consistent, judgment" in making coding decisions (D. R. Garrison, personal communication, December 14, 2007). The decision to code only the highest phase found in each full message calls for careful reading. Coding decisions are often made due to one key sentence or phrase. However, messages also exist that are more direct in terms of coding, such as the next example:

> Message 90
> Anyway, I think we agree that the isosceles triangle has the maximal area. To apply this thinking to the n-gon problem, I think we need to:
> 1) construct a regular n-gon and show that any change to the characteristic triangles would reduce the area, or
> 2) construct a non-regular n-gon and break it into constituent triangles (an arbitrary interior point can be chosen for the construction). Then show that, unless the adjacent n-gon sides are equal, the sum of the areas of any two adjacent triangles can be increased, therefore the n-gon area is not maximal
> It looks like you're advocating for option #1. I'm fine with that, but I'm having trouble nailing everything down. On the other hand, with option #2 we could merely assume the non-regular n-gon has the maximal area, then show that this leads to a contradiction.
> I definitely agree: we need pictures!

This student's message was coded as Integration by several indicators. He or she acknowledged agreement with another student on the idea that an isosceles triangle has maximal area. The student then built on this idea by presenting two approaches to solving the problem and commenting on the pros and cons of each. Group members connected ideas to create a solution, showing signs of convergence which is indicative of the Integration phase.

A new indicator of Integration, "Convergence through disagreement," was added by the researcher to indicate when students contradict one another, but in a constructive way that leads to deeper analysis of the topic. While training to use the coding protocol,

the researcher and second coder both noticed that there were no messages indicative of

"divergence within the online community" which was associated with the socio-cognitive

process "unsubstantiated contradiction of previous ideas." Instead, messages were

recognized as contradictory in nature, but with substantiation that led to further analysis

of the topic at hand. Thus a new indicator was added to the coding protocol. This is

demonstrated in the following exchange of messages:

> Message 192
> Student A: Angles can be proven congruent by using the perpendicular lines and alternating interior (or another such angle pair) angles.
> Or at least that is one way to get our angles congruent!
>
> Message 193
> Student B: Sorry, I'm not following that. I'll try to be a little more specific:
> Let's say we have a n-gon with congruent sides. We want to show that, for maximal area, its interior angles must also be congruent.
> We have been prompted to produce a proof that, for triangles of fixed perimeter with one side constant, the isosceles triangle has maximal area. And, of course, we can render a regular n-gon into n isosceles triangles. But I don't think this proves that the regular n-gon is maximal. (For one thing, the perimeters of the component triangles are not necessarily fixed – we can make a variety of different triangles.)
> What do you think?

Student B analyzed the comment from Student A's previous posting by disagreeing, but

the message promoted further analysis of the topic. These types of messages were not

coded as Exploration because the researcher and second coder agreed that such postings

go beyond sharing of information. Indeed, the students are constructively putting forth

and analyzing arguments in a way that results in further integration of ideas. Another

example of this type of posting is given below:

> Message 77
> I like your ellipse ideas – will work on it a bit. I am not so certain about your description of how to use the isosceles triangle then. I think just connecting the

vertices to make those triangles would leave us with an inner space we'd need to maximize also. I "see" the isosceles triangles originating at the center of the polygons—a 5-gon would have 5 triangles originating from its center with each side segment as the base. Decomposing the polygon that way leaves no interior area unaccounted for.
Thoughts?

The key sentence in this posting is "I am not so certain about your description of how to use the isosceles triangle then." The student goes on to explain the reasons for his or her uncertainty and asks for further input. In the process of presenting and critiquing each other's approaches, students move closer to a final solution. A solution proposed by a student also indicated integration.

One of the four indicators of integration in the cognitive presence coding protocol is "Creating solutions." This indicator was problematic, in that students often presented their solutions as attached documents. The accompanying message would simply indicate that the solution could be found in the attachment. After opening several of these, the researcher recognized that the attached student work was merely a report that then became the vehicle for continued discussion. An example follows:

Message 67
I know I am kind of late, but I just got this written up to prove that the maximal area given a constant perimeter is indeed going to be a circle. ….

Let me know what you think, I hope it all makes sense!!!

Attached to the posting was the student's solution. All postings where the student explicitly acknowledged an attachment as a solution were coded as integration. The attachments themselves were not coded.

Resolution: The final phase, Resolution, accounted for only 28 of the 826 postings coded to the four phases of the Practical Inquiry Model. The indicators for resolution include testing solutions or demonstrating vicarious applications to the real world. The following example represents the actual testing of an idea in the real world:

> Message 267
> This is neat as I just did this with my Algebra 2 class today as part of our investigation. We started out with 24 feet of fencing for a garden, and then worked to find different possible dimensions that would form a 24 foot perimeter. Newt we found the area for each set of dimensions, and plotted the width vs. area to see the parabolic graph. We then found the vertex, and the real life meaning of the vertex of this graph. I asked if it was appropriate to plot the data with a smooth line or just a s a scatter plot and the students discussed why. We compared the dimensions of the garden producing the maximum area and discovered it was square. We discussed if it would be square for any length of fence or just 24 feet. Tomorrow we will find the equation for the length in reference to the width, and the area in reference to the width. We will also examine the real life meaning of the roots of the width-area graph. It's been working pretty good so far!

As part of an assignment involving a mathematical problem, students were asked to reflect on some part of the problem that could be separated off and given to their students. They were to share the actual problem they would pose and the level of student for which it was appropriate in the discussions. Thus, the posting above is the result of a direct requirement of the class. An example of resolution that was not based on a task requirement follows:

> Message 360
> I suppose this is not a great example, since I mentioned it in my last group, but I use Eratosthenes Sieve every year to have my students find prime numbers to 100 – I just never knew that's what it was called or the story behind it.
> I think that this year I will tell the story and see if kids can come up with a method for finding prime numbers before I show it to them. It will be more interesting and hopefully stick better that way.

This student made a connection between what he or she was already doing in the classroom (finding prime numbers) and the topic at hand in MATH 500 (the story of the Sieve of Eratosthenes). The individual then went on to indicate how it could be implemented in his or her classroom in the future. The initial discussion question did not require an example of a classroom application, yet the student, on his or her own, extended the ideas to the classroom.

Table 2 summarizes the categorization of the 976 messages coded using the coding protocol for cognitive presence. The number and percentage of messages coded to each category are presented. The percent of messages coded to each of the PIM phases when the "Comment" and "Teacher presence" categories are excluded is shown in the fourth column, and in the last column the results are narrowed even further by leaving out the required postings.

Table 2

Overall Category Counts for Postings

Category	Count	Percent of All Messages	Percent of PIM messages	Percent of PIM RP excluded
Triggering Event	6	.61	.73	1.17
Exploration	631	64.65	76.95	63.23
Integration	155	15.88	18.90	30.16
Resolution	28	2.87	3.41	5.45
Comments	88	9.02	NA	NA
Teacher Presence	68	6.97	NA	NA

Analysis of Cognitive Presence by Student

The 905 student discussion postings were disaggregated by student to analyze the number of postings each member of the class contributed to each phase of the Practical Inquiry Model. Figure 3 summarizes this data for each of the nineteen students. They were randomly assigned a gender for anonymity purposes in the rest of the study.
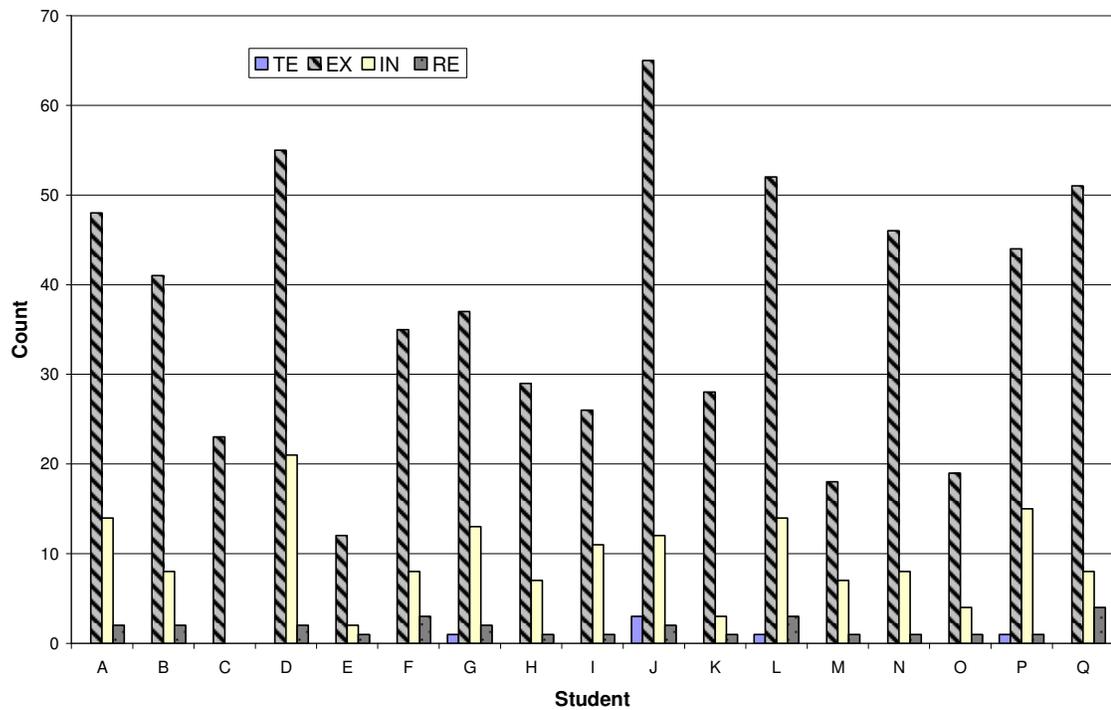
Figure 3. Number of postings per student for each phase of the Practical Inquiry Model.

As stated previously, the highest number of postings overall (64.65%) was coded to the Exploration phase. As shown in Figure 3, this was also true for each individual student. In the most extreme case, 65 or 70.65% of Student J's messages were coded as Exploration. Of the students who completed the class, the lowest individual ratio of Exploration messages was posted by Student M, who only posted 28 messages overall.

As discussed in Chapter 3, the number of postings that were "required postings" was noted during the coding process. They did not occur in the natural flow of an ongoing discussion; rather, they were required assignment postings similar to the scenario of a student turning in an assignment physically in a face-to-face class. If a single message was a combination—a required posting supplemented by additional statements that contributed to the online discussion—the message was coded according to the additional statements made. All required postings were coded as Exploration as they represented an exchange of information. When required postings are excluded from the group of postings coded as Exploration, the extreme differences in number of postings per phase are minimized as seen in Figure 4.
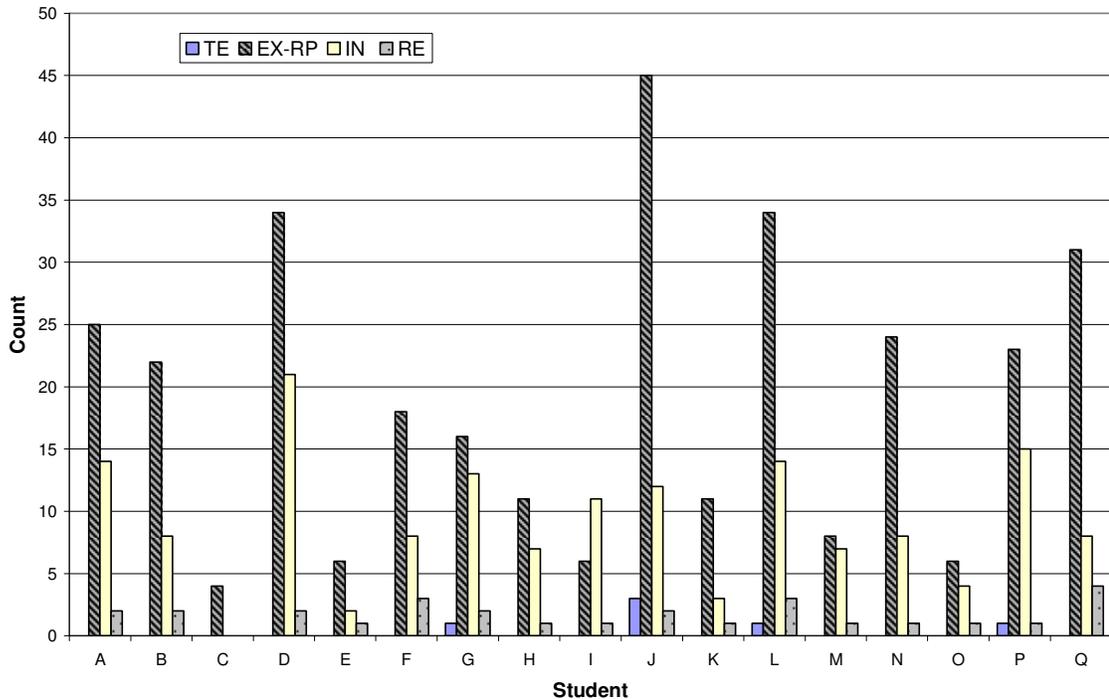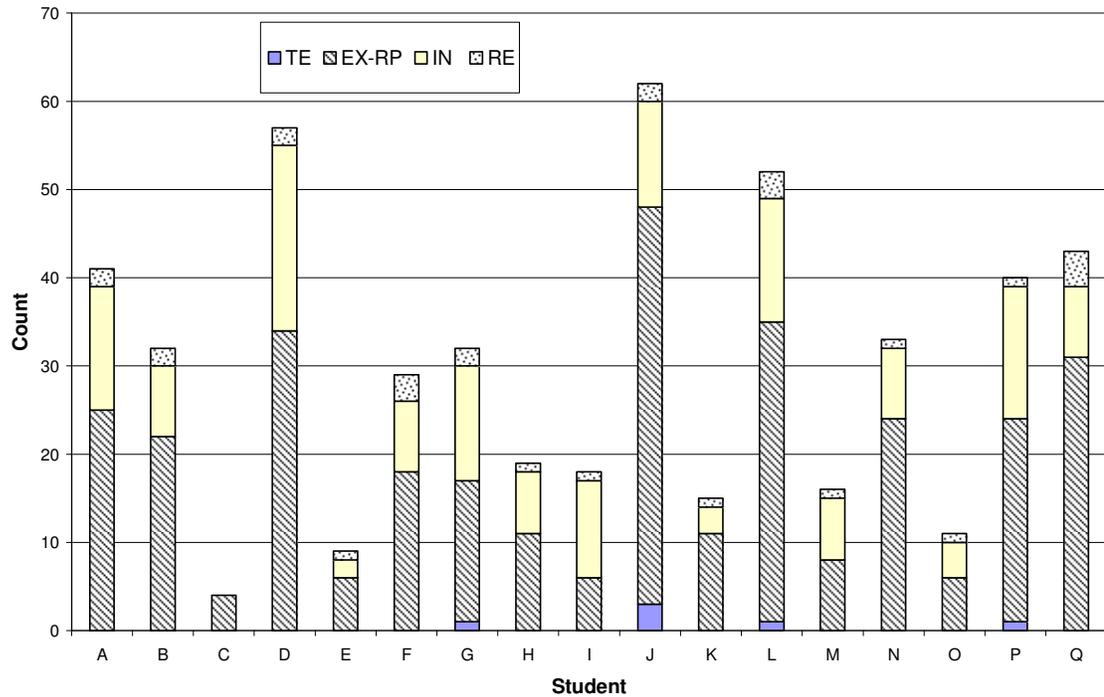

Figure 4. Number of postings per student per phase with required postings removed.

The second highest number of postings was coded to the Integration phase for the entire class and also, as shown in Figure 2, for each individual student except for Student I whose Integration postings exceeded the number of Exploration postings when required postings were removed. Thus, initial differences seen between the number of postings in the Exploration phase and the number of postings in the Integration phase are not as extreme when required postings are excluded.

For each individual student, the number of postings coded to the four phases of the Practical Inquiry Model varied from 15 to 82. The lowest number of postings was from a student who dropped the course midway. The lowest number of postings for a student who completed the course was 23. To better compare individual student differences, the distribution of postings in each phase of the Practical Inquiry Model for each student was analyzed. Figure 3 visually relates the total number of PIM postings each student contributed to MATH 500 to the proportion of those postings that were coded to each individual phase.

Figure 5. Number of postings per phase of the Practical Inquiry Model by student.

The students with the highest number of postings overall typically were the same students who had the highest number of integration postings. Quantity does not necessarily imply quality in discussion postings, but in this case they are related. Student D had the highest number of postings coded as Integration at 21. Students P, L, A, G, J, and I (in descending order) had Integration postings ranging from 11 to 15 as shown in Table 3. The rest of the students had from 0 to 8 postings coded as Integration. The researcher grouped the top seven posters as "high performers" since there was a jump of three messages to the next person. Of these seven students, two of them (G and I) were not among the top seven students regarding high number of overall postings.

Table 3

Students with highest number of Integration phase postings

Student	Total Postings	Integration	Percent Integration
D	78	21	26.92
P	61	15	24.59
L	70	14	20.00
A	64	14	21.88
G	53	13	24.53
J	82	12	14.63
I	38	11	28.95

Group composition and student demographics help to illuminate these findings. The case

of students G and I may be partially explained by responses they provided on their post-

course surveys. Student G stated voluntarily at the end of the survey:

> I am personally not a huge fan of online courses because of the required
> discussions. I am very much an introvert and like to study on my own. I
> frequently did not want to "discuss" everything…but it was required for a good
> grade.

By this comment this student clearly portrayed her dislike for online discussions. This

perhaps explains why the student did not have as many postings as the other high

performers. Yet the requirements of the class were to participate in discussions, thus she

did post which resulted in 24.53% of her postings being coded as Integration. Student I

made a similar comment in a post-course survey response:

> While most tasks involved some discussion/interaction it seemed forced, like I was doing it just because I had to. I noticed that other groups had much more interaction and wish we could've switched up groups more. That might have spurred me to be more social.

Student I also referenced the feeling of being "forced" to post as a course requirement and goes on to speculate that group composition might have played a part in his feelings about discussions. Student I had the highest percentage of postings coded as Integration as shown in Table 2, yet only had 38 messages coded to the four phases of the PIM. Both students clearly posted high quality postings, but did not post a high number of postings when compared with the rest of the class.

Another unique example is Student Q. He posted 64 messages, the fourth highest total among all 17 students, and yet only eight of those postings met the Integration criteria. However, it would be unfair to label Q as a low-level thinker without looking at the dynamics of his discussion group. It included Student I, who as discussed in the previous paragraph, clearly stated his feeling of being forced to post discussion messages. Also included in this group were students E, K, and O. Student E dropped out of the course midway through the semester. Students K and O posted a total of 39 and 28 messages each. When required postings were excluded the students had a total of 15 and 11 postings respectively coded to the four phases of the PIM over the course of the semester. Their numbers were higher than only two other students in the class, one being the person who dropped midway through the term. Students K and O were also chronically late with postings throughout the semester.

The seven students with the higher numbers of Integration phase postings were analyzed for similarities and differences. This group included four women and three men

of varying ages that taught mathematics at either the high school, community college, or university level. The highest level of mathematics the four high school teachers taught in the last two years was algebra or geometry, while the lone community college instructor taught pre- and applied algebra, and the university instructors taught calculus or higher. Six of the seven students had taken three or more online MMTE courses prior to MATH 500 in Fall 2007. The student who had less experience in online MMTE courses had taken more than four online classes using the WebCT platform previously, thus his inexperience existed with the MMTE program itself, not in online learning or using WebCT. Of these seven students, five held Bachelor of Science degrees in Mathematics. The two people who did not have a B.S. in Mathematics differed from the other five in several ways: each was over 50 years old, and each had earned a degree in a subject other than mathematics with a minor in mathematics. Online learning has been found to work particularly well for mature students (Gunn & McSporran, 2003) which might explain why these non-mathematics majors were in the high-performing group.

The students with the lowest number of Integration postings in the class were also compared. Table 3 shows the ten lower-performing students in the course, including the student who dropped out mid-semester, and their corresponding posting totals. Integration postings ranged from 0 to 8 and total postings ranged from 15 to 64. As noted previously, student Q had a high number of total postings when compared to the entire class, but showed a low ratio of Integration postings when compared to students with a similar number of total postings.

Table 4

Students With Lowest Number of Integration Phase Postings

Student	Total Postings	Integration	Percentage Integration
Q	64	8	12.5
N	55	8	14.55
F	46	8	17.39
B	52	8	15.38
M	26	7	26.92
H	37	7	18.92
O	24	4	16.67
K	32	3	9.38
E	15	2	13.33
C	23	0	0.00

One student chose not to participate in the study and provided no background information. The description of the students in this group is thus limited to the nine students who completed the questionnaire. Four females and five males comprised this group of students. Seven of the nine students earned secondary mathematics education degrees and one of these students also earned a B.S. in Mathematics. One of the remaining students held a B.S. in a scientific degree other than mathematics and the final student held a B.S. in Mathematics. Five of the nine students taught high school mathematics, three taught middle school mathematics, and one taught both levels.

The high school mathematics teachers and the teacher who taught both high school and middle school stated that the highest level of mathematics they taught in the last two years was either pre-calculus, calculus, or some other advanced math. It is worth observing that the high school teachers who self-reported teaching higher-level mathematics (e.g., calculus) were in the group that posted the fewest Integration messages. In addition, the four students who currently taught middle school were among the low-performing group for number of Integration postings.

Four of the students had 0-4 years of mathematics teaching experience, three had 5-9 years, and two had 10-14 years. The two students with the most teaching experience in mathematics had four or fewer postings coded to the Integration phase. Four of the students in this group had never taken an online MMTE course prior to the Fall 2007 course; only one of the four was taking an online course using the WebCT platform for the first time. The five other students, in contrast, had taken three or more online MMTE courses in the past. Thus students were either inexperienced, or very experienced with online MMTE coursework.

The postings that were coded as Resolution ranged from 0 to 4 for a single student. Student Q, the student with a high number of postings but a remarkably low ratio of Integration postings, had the highest number of Resolution postings (four). Students F and L each posted three messages at the Resolution phase. Five students were attributed with two Resolution messages, and eight students posted one Resolution message. Student C had no postings coded at the Resolution phase. Student C's postings were all at

the Exploration phase; he also posted the least number of messages among students who

stayed in the class the entire term.

In the Resolution phase, to reiterate, students take their newly acquired

knowledge from the Integration phase and vicariously test it or apply it to the real world.

In the context of the MMTE program, the "real world" most often translates into the

teacher's own classroom. When coding postings of this nature, the researcher made note

of messages that were the product of a direct request in the assignment instructions in

order to distinguish between "naturally occurring" resolutions and "forced resolutions."

Nineteen of the 28 resolution postings were coded as forced. The following posting from

the instructor gives an example of the instructions that would force a resolution response:

> Message 239 (excerpt)
> NOW…Here is what we do for closure of this problem solving section of the unit.
> We need to reflect on what parts of the problem can be separated off and given to
> our students. I would like in your group folders each of you to identify a problem
> that we could pull out [of] our work on Dido's problem and state how you would
> present it to a class and what the level of the class would be.

Each of the nine postings that occurred naturally was posted by a different student.

Assignments in MATH 500

As stated earlier, 976 of 1,111 postings were coded from the Fall 2007 MATH

500 online course discussions. These included instructor and student postings that were

coded as either Comment, Teacher Presence, or in one of the four phases of the Practical

Inquiry Model. As shown in Figure 6, the layout of the discussion threads does not

clearly differentiate between separate tasks. Some discussions are specific to a particular

Discussions

Compose message ⋮ Search Topic settings

Click on a topic name to see its messages.

☐	Topic	Unread	Total	Private	Anonymous	Locked
☐	Main	0	6	☐	☐	☐
☐	Notes	2	2	☐	☐	☐
☐	Introductions	0	34	☐	☐	☐
☐	Assignments	0	54	☐	☐	☐
☐	F-O-B-A	0	61	☐	☐	☐
☐	D-L-K-C	0	59	☐	☐	☐
☐	I-N-G-E-M	0	52	☐	☐	☐
☐	Q-H-J-P	0	74	☐	☐	☐
☐	NEW GROUPS!	1	1	☐	☐	☐
☐	F-L-G-P	35	183	☐	☐	☐
☐	O-K-E-Q-I	24	123	☐	☐	☐
☐	B-C-M-H	12	111	☐	☐	☐
☐	A-D-N-J	23	218	☐	☐	☐
☐	Unit Five – Non-Euclid Discussion	0	54	☐	☐	☐
☐	Geometry Lessons	0	39	☐	☐	☐
☐	Unit Six Ideas and Leads	0	7	☐	☐	☐
☐	Unit Six Questions	0	17	☐	☐	☐
☐	Book Reports	1	16	☐	☐	☐
	All	**98**	**1111**	Update		

Figure 6. A snapshot of the discussion page from WebCT for the MATH 500 course

task; others blend message threads from several tasks. The instructor referred to blocks of

assignments as "units" as the course progressed. Six units were assigned over the fifteen

class weeks, and each unit had various sub-components that were labeled according to the

assignment for that component. Students discussed Unit One in four groups: F-O-B-A, D-L-K-C, I-N-G-E-M, and Q-H-J-P. These groups changed for Unit Two which can be seen in Figure 6. Students stayed in these newly formed groups for Units Three and Four also. Units Five and Six were discussed as an entire class, thus there were no group folders to post to. The next figure is a snapshot from WebCT of group F-O-B-A's Unit One discussion folder. As seen in Figure 7 there are many threads contained in the discussion folder. All postings regarding the Problem of Dido for this group were posted to one thread. In contrast, students created their own threads in order to post their biographies. The instructor posted the thread "Summaries" but none of the students posted to that thread, perhaps because they were not sure what it was for.

Status		Subject	Author	Date
0/3		Student F my response		
0/3		Student B's Response		
0/33		Dido's problem		
0/2		Student A's Response		
0/3		Student O's Response		
0/1		Summaries		
0/4		Student B's Eratosthenes		
0/5		Student F's Pythagoras		
0/1		Student A's Archimedes		
0/2		Student O's Eudoxus		
0/4		Questions on assignments		

Figure 7. Group F-O-B-A's discussion threads for Unit One.

Table 5

Breakdown of Postings by Assignment

Assignment	Thread Subject Line Description	Number of Postings
1	Reading Assignment	59
2	Problem of Dido	146
3	Biography	36
4	Reading Summary	39
5	Hodgkins Discussion	25
6	Unit Two Problem	105
7	Unit Two activity	31
8	Unit 3 Number and Operations	65
9	Unit Three Math problem	61
10	Unit Three History Reading	41
11	Final Part of Unit 3	53
12	Unit Four	21
13	Unit 4 Math Problem	44
14	Unit 4 Math Problem	31
15	Unit 4 Fibonacci Part 2	17
16	Unit Four Lesson Development	100
17	Unit 5 Geometry Problem	54
18	Geometry Lesson Assignment	24
19	Unit 6 (The Shortened Version)	24
Other	Assignments sent directly to instructor, book report	NA

After analyzing individual threads within each group discussion, the researcher synthesized the discussion messages into 19 assignments or tasks for coding purposes. The intent was to group discussion messages according to differences in the type of assignment the students were asked to complete. The researcher gave each assignment a title based on the subject line used by the instructor in the assignment folder. Table 5 lists the assignments and the number of postings associated with each assignment. The assignments themselves are briefly described in the following section.

Nature of Assignments

In this section, each MATH 500 assignment is potentially discussed from three perspectives: 1) a description of basic requirements of the assignment; 2) references to messages and activity in the discussion; and 3) a summary of content analysis results. In particular, Assignment 2 is discussed in depth.

Assignment One

The first assignment required the students to read a chapter from a course text and then to post a one-page answer to the instructor-prompted question, "What are the main things Jones thinks we can learn by studying the history of mathematics?" Dr. Brook added that the students' answers should conclude with their own thoughts. The second part of the assignment required students to read an article on a strategy for embedding historical considerations into their curricula, then to write a half-page summary explaining what the strategy used in the article meant to them and illustrating the strategy with a specific example.

The students were given six days to complete both parts of the assignment. The instructor stated in this first assignment posting, "It is really important to read all of your group postings and to log in frequently to the course. There are many parts of the assignments where group interaction is needed. Your peers depend on you and you will benefit by working with them." The class was divided into four discussion groups assigned by the instructor. One week after the initial assignment posting, students were asked to post a long paragraph that identified specific features they noted in other group members' postings that they would include if they were to revise their own summaries.

Results of content analysis of the 59 postings are summarized in Table 6. This assignment resulted in the fifth highest number of Integration postings, and nearly half of the Exploration postings were required. (Note: In each table reporting content analysis results for an assignment, the number and percentage of all postings in the Exploration phase will be listed first, followed by the values related to "required postings" (RP) in the next row.)

Assignment 2

The second assignment required students to work on the mathematical Problem of Dido, more commonly called "the isoperimetric problem." The instructor identified this as a difficult problem drawn from the history of mathematics and noted that working on the problem should teach the students two things: 1) The ancients thought at a very high level and did not have the tools we have today to apply to problems, and 2) Difficult problems can still be used in teaching by looking at easier cases and simpler related problems. The students were given approximately two weeks to discuss the Problem of

Dido. Throughout the two weeks the instructor posted whole-class hints and strategies for

attacking the problem. Towards the end of the second week the assignment took on a

pedagogical focus as students were asked to share examples of parts of the problem that

could be isolated and given to their own students. They were given approximately four

days to accomplish this at the end of the two weeks.

The following example, where Student F from Group 1 expresses his need for

help in understanding the assigned problem, demonstrates the influence of teacher

presence. (Note: misspellings have been corrected by the researcher.)

> Message 247
> Ok here is where I swallow my pride and announce that I still do not understand
> how to prove Dido's problem. I have read just about everything written as well as
> the hints however I feel like I am getting bogged down in proof speak. So if
> anyone would like to take [pity] on me and maybe try to explain Dido and a plan
> of [attack] I would really appreciate it. As it stands I understand the concept but
> not how to prove it. I will continue to reread what everyone [has] written and
> maybe just looking at it again will help
> Thanks!

This message was posted at 6:35 p.m. The next response came at 1:26 p.m. the next day

from the course instructor:

> Different individuals will tackle the problem at different levels. There have been
> so many ideas thrown out on the table that sorting through all the "Logic" can be
> difficult. I would be satisfied if you would focus on proving [that] the triangle
> with perimeter P that has the most area is the equilateral triangle and that the
> quadrilateral with perimeter P that has the most area is the square. These problems
> capture the spirit of [D]ido's problem and most of the basic techniques used in the
> proof of the more general theorem about n-gons.

The next morning Student F requested that the instructor look at an earlier posting and

offer his thoughts on the student's approach to the proof:

> Dr. Brook,
> Will you look at the proof I posted earlier in the Dido discussion and tell me what you think and where I should go from there?
> Thanks

The instructor did so and provided a thorough response that contained Student F's proof along with comments inserted in the proof. The next day Student F responded with the following posting:

> Dr. Brook
> I read your comments and I think I have fixed the problem. Tell me what you think….

This ended the exchange. Of interest is the fact that once Dr. Brook responded to Student F, all further postings from the student were directed to the instructor, no longer to the group. Had the instructor not jumped in, would Student F have continued to direct comments to the group? And in turn would the group have responded? Was help provided too soon, or was 18 hours long enough to wait?

Student F's initial message of confusion was also responded to by one student in Group 1 (F, B, O, A) approximately one hour after the initial post. Student B asked what parts of the problem made sense to Student F. Student F responded approximately one hour later and conveyed her thoughts on what she understood. Student B did not respond for nearly four days, by which time the instructor had already requested "closure on the unit." It should be noted that this group, which also included students O and A, never reached a consensus or resolution on how to solve the mathematics problem. Little interaction occurred and zero postings were coded as Integration, even though this assignment had more Integration postings than any other assignment overall.

Integration postings were identified in Group 2 (I, N, G, E, M). Again, this group's activity told an intriguing story. Student M did not contribute to the postings at all. Student I was the first student to post, and suggested a strategy for approaching the mathematical problem. In turn, Student G acknowledged the strategy as "a good place to start" and then proceeded to offer two of his own approaches to follow. Student N acknowledged the approaches suggested by students I and G, but did not add anything to further the ideas. At this point Student I proposed a solution to the first part of the proof and then suggested a strategy for finishing the proof. Student G worked on the second half of the proof, describing his thoughts and struggles in three postings. No one in the group responded to his postings. Two days later, Student I posted a message stating that he or she finished the problem and would post the solution the next day.

At this point Student D, who was from another group, asked Student I for a hint on how to approach a certain aspect of the proof. Student I did not respond, but Student E, who up to this point had not posted a message, responded. Seven days after the first message was posted in this group Student E and Student D, (who was not assigned to the group), briefly exchanged thoughts. No one else from the group jumped in until Student N posted a message acknowledging her struggles with the problem and asking for help. No one responded to this message, but Student I, approximately ten minutes later, posted an attachment with his proof written up acknowledging an error he found in his first write-up and then posting a final version. The last posting is a final proof submitted by Student N.

This disjointed sequence of postings indicates a lack of collaboration as students proceeded with the problem. There was little or no evidence of students building on the ideas of others. There was convergence on how to approach and resolve the problem, but it occurred on an individual basis. Student I shared his thoughts about the problem intermittently, letting the group know how he was progressing on the proof, but did not acknowledge other people's postings. Student G worked in the same fashion. The group discussion became a sort of information repository rather than a forum for sharing ideas. Student N expressed a lack of understanding of the problem and asked specifically for help, but never received a response.

Group 3 (D, L, K, C) had the most postings coded as Integration in this assignment. Students D and L exchanged fifteen messages over four days before student K posted a message stating "I feel like I am very much behind. I will re-read Dido's problem and your thoughts and comment tomorrow. Sorry for the delayed participation." This student posted two days later and critiqued the work of Student L and verified the mathematical steps of Student L's proof. Student K again posted two days later acknowledging confusion, and then posted again saying that since he had nothing to offer to move the group forward, he would piece together what had been done so far and write up a summary. This was never done. Students D and L built upon one another in attempting to solve the Problem of Dido and contributed to all but one of the postings coded as Integration. Student C did not contribute to the group at all. However, Student J from Group 4 did pose a few questions within this group in an effort to justify her thinking.

Students Q and J from Group 4 (Q, H, J, P) posted the most messages (15 and 13 messages respectively) while students P and H posted 5 and 4 respectively signaling an imbalance of postings. Students Q and J interacted frequently with one another, and students D and L from Group 3 also posted messages. Student D acknowledged that he posted in the group by accident, while Student L acknowledged she was in a different group but wanted to offer her thoughts.

Student H posted a suggestion for consideration at the start of the discussion but did not post anything besides a comment until six days later when she suggested another possible solution approach. Students Q and J offered suggestions and built upon the posting of Student H, but at this point the discussion dissolved. Student P's postings were random and asked for information from the other students in order to help her understand the problem itself. Her postings did not add to the depth of the discussion or further it in any way. Students Q and J interacted with one another the most and were responsible for pushing the discussion beyond the Exploration phase. Every posting coded as Integration was attributed to these two students.

This assignment contained the highest number of postings overall (see Table 6). The majority of postings were coded as Exploration, with no required postings. This assignment also contained the highest number of Integration postings, Resolution postings, and Teacher Presence postings when compared to every other assignment. However, twelve of the 15 Resolution postings were coded as "forced." Recall that resolution postings were noted as "forced" when the students were required by the instructor to apply the topic they were studying to the classroom.

Assignment 3

The third assignment, posted during the second week of the Problem of Dido

discussion, required students to write the biography of an assigned famous ancient

mathematician using Wikipedia, the online encyclopedia, as source material. Students

were given approximately four days to post their biographies to a discussion folder. There

were no discussion prompts posted. This was a stand-alone assignment, which served as a

pre-cursor to Assignments 4 and 5. Students did not realize the purpose of the assignment

until later, unlike most assignments which were more up-front in their objectives.

Table 6

Unit 1 Content Analysis Results

Category	A1 #	A1 %	A2 #	A2 %	A3 #	A3 %
Comment	3	5.08	16	10.96	7	19.44
Teacher presence	3	5.08	20	13.70	6	16.67
Triggering Event	0	0	4	2.74	0	0
Exploration	38	64.41	65	44.52	20	55.56
RP	17	44.74	0	0	17	0
Integration	13	22.03	26	17.81	1	2.78
Resolution	2	3.39	15	10.27	2	5.56

A total of thirty-six postings were coded as shown in Table 6. Of the 20

Exploration postings for this assignment, 17 were required postings that satisfied the

assignment instructions. Thus it was not discussion-oriented.

<u>Assignment 4</u>

With the fourth assignment, Dr. Brook launched Unit 2 and shuffled the students into four new discussion groups. As stated previously, the students were not regrouped in discussion groups again the rest of the semester. Students were required to read a chapter about the uncertainty that exists regarding the historical accounts of early Greek mathematics and mathematicians. They then wrote an ERMO summary, using the chapter to support their opinions on the various biographies that were written by their group members in Assignment 3. In essence they were to critique the biographies for "believability." The students were given five days to post their summaries and opinions. For this ERMO students were not specifically required to comment on one another's summaries as in Assignment 1, although Dr. Brook described this as an important component of the ERMO during his interview.

Throughout the course, students noted the "newness" of studying the history of mathematics. The following exchange between Students L and G provides an example:

> Message 306
> Not having had a history of mathematics course previously, nor having had instructors who wove that history into their courses, I feel I am very unprepared to evaluate the accuracy of a source's writings. I have a book entitled "Euclid's Window-the Story of Geometry from Parallel Lines to Hyperspace" that I have enjoyed tremendously. Now as I revisit this text, I read material presented as factual that Hodgkin would report as not substantiated at all. I feel a bit overwhelmed at the thought of sifting through a text like I was one of those "mythbusters" to whom another student referred. Sigh…
>
> (There is an attachment containing an ERMO summary as part of this message)
>
> Message 316
> I know how you feel, Student L!

> I have a set of books called "Mathematicians Are People Too" with stories and such about ancient mathematicians their lives and their contributions…and now… it's a bit disheartening. I wonder how much of it is remotely true?

In Message 306, Student L connected to her personal experience of doing the ERMO summary and shared it with the class. This message was coded as Integration. Student G built upon the idea presented by agreeing with Student L and then explaining why she agreed. This message was also coded as Integration. These excerpts demonstrate that Integration can occur outside of the specifics of an assignment, and reaching a solution is not necessarily required.

A total of 39 messages were coded for Assignment 4 as shown in Table 7. Of these messages, eight were coded as Integration even though there was not a significant amount of discussion occurring. For example, 21 messages of the 39 were Exploration messages, and of these Exploration messages 17 were required postings.

Assignment 5

Two days after Assignment 4 was due, Assignment 5 was posted as a follow-up discussion question regarding the chapter reading from Assignment 4. Groups were asked to discuss the question: "Should teachers use stories from the history of mathematics in their teaching of mathematics? If so, how? If not, why not?" Students were instructed to propose an answer to the whole class while in their small groups, and to explain, justify, and provide examples. They were not given a time line other than "start posting immediately." (Minutes after this assignment was posted, Assignment 6 was posted which also stated "start responding immediately.")

Of the 25 postings from this assignment, 11 were coded as Integration. In each group, after an initial message answering the discussion questions was posted, several students built upon that posting rather than posting their individual thoughts. Common opening phrases were: "I agree," "I totally agree with you," "I can totally see your point," "I agree with both of you," and "I know what you mean." These phrases were then followed up with additional ideas that built upon the prior postings. Surprisingly, the original assignment instructions were not followed in the postings. Although students did explain why they felt history should or should not be used in the classroom and attempted to justify their stance, not all students provided examples and not a single group proposed an answer to the whole class as requested by the instructor. In general, students posted one or two messages in the discussion group, so a continuous back and forth chain of discussion did not occur.

Assignment 6

In Assignment 6 the students explored a geometric construction method for trisecting angles. They were to decide under what conditions the method worked, if any, and provide a proof. After five days of exploration, the instructor intervened with several suggestions for starting the proof of a theorem that would in turn show the construction method is impossible. Students were also asked to share ideas for using related parts of the problem in the mathematics classroom at the level they taught. This assignment aligned with Assignment 2, the Problem of Dido, in terms of content and instructions.

Group 4 (A, D, N, and J) did not post any classroom ideas at any point in the discussion, thus failing to meet all requirements of the assignment. Students E, K, P, and

C, who were from varying groups, also did not post classroom ideas to their respective groups. Student C, as noted previously for lack of participation, posted only once to his group and did not contribute a Web site or a classroom application as requested in the assignment.

Student Q was the first person to post a message to the discussion thread of Group 2 (I, O, K, E, O), where he suggested ideas for the problem. At no point did anyone else in the group provide ideas. Student I, discussed in more detail below, did provide solutions. At one point Student Q posed a question about a method that Dr. Brook proposed and Dr. Brook responded to his question. That was the only interaction Student Q directly received.

Student I posted the second message in the group and immediately provided a possible solution to the trisection problem. Two days later he posted a second, alternative method for solving the problem. Student I did not interact with others in the discussion; instead he simply presented his work for others to see. These postings were coded as Integration because they were identified as solutions. Although the postings followed the "letter of the law" in meeting indicators for Integration, Student I did not integrate intellectually with others in his group.

Group members O, K, and E each posted one message during the entire discussion on the trisection method. The posts of Students O and K follow:

> Message 384
> Wow Student I! You're like 47 steps ahead of me on this assignment! I read over your proof, but my mind doesn't fire on all cylinders on a Sunday afternoon. (Nappy time!) I've printed it off and will try to read it again in a little while. Sorry I'm behind on this one.
> Student O

Message 429
Ok now that I am with everyone on this. I looked over Student I's proof and that is also the direction that I was heading. Student I you are way ahead of me though. I was very stuck on the not using any trig. Glad you are part of this group. Thank you for all your hard work.
Student K

Student O's posting acknowledged that she was behind. The discussion lasted four more days after that posting, but Student O never posted again. Student K's message was posted two days after Student O's and stated that Student I's approach was similar to what she was thinking of doing. Student O did not contribute any other postings to the discussion. Student E's single posting contained a personal narrative about his past experience with the trisection problem.

Assignment 6 resulted in 105 overall postings which was the second highest number of postings in the course. This assignment had the third highest number of postings coded as Integration (see Table 7) and the second highest number of Resolution postings. Of the six postings coded as Resolution, all were categorized as "forced." This assignment also had the highest number of Teacher Presence postings, second only to Assignment 2 which was a similar assignment.

Assignment 7

Assignment 7, which involved an activity called Pythagoras' Quandary, composed the last part of Unit 2. Using a "pan balance applet" online, students were asked to find a strategy that would always work for balancing the pan using only one kind of object on the left side and one kind of object on the right side. After being given two days to explore the applet, students were asked to share their thoughts on what it means

for two quantities to be commensurable or incommensurable and what that might imply

about the existence of irrational numbers.

Group 1 (F, L, P, G) did not post messages to the folder until six days after the

initial discussion questions were posted by the instructor. Excerpts from the first two

postings in Group 1 follow:

> Message 512
> I guess I must have been working on the other stuff and must have blanked that there was the quandary activity…I found it and played with it though and I guess I will talk about it here? I thought that was a pretty fun little applet. I had always heard commensurable but was never really thought about what it meant I suppose, there's a common unit. After this activity I was trying to relate this to irrational numbers and after doing this I would think that there would be doubt that …(message continued about irrationals)

> Message 522 (in response to Message 512)
> Yeah…I think we've got too many irons in the fire right now. The Quandary was a pretty nice applet to work with. My only problem is that the idea of incommensurable numbers is somewhat advanced…I'm uncertain as to what grade level this would be for… and yet the applet is very simplistic. It seems like students old enough to be challenged by the math concepts might be bored by the applet. That's kind of how I felt with it, it was cute, but I'm not sure it furthered my understanding. Maybe if the applet…(message continued about the applet)

Note that Student P, who posted Message 512, attempted to address all of the questions

posed by the instructor. On the other hand Student G, who wrote message 522, focused

on the applet rather than the discussion questions. After these first two postings, the rest

of the group messages seemed to follow the lead of Student G. Instead of addressing the

assignment questions, they presented ideas for how to implement the applet in their

classroom.

Table 7

Unit 2 Content Analysis Results

Category	A4 #	A4 %	A5 #	A5 %	A6 #	A6 %	A7 #	A7 %
Comment	9	23.08	1	4.00	6	5.71	4	12.90
Teacher Presence	1	2.56	0	0	15	14.29	2	6.45
Triggering Event	0	0	0	0	0	0	0	0
Exploration	21	53.85	12	48.00	62	59.05	17	54.84
RP	17	80.95	0	0	1	1.61	0	0
Integration	8	20.51	11	44.00	16	15.24	7	22.58
Resolution	0	0	1	4.00	6	5.71	1	3.23

Assignment 8

Unit Three commenced with students completing another ERMO summary and responding to the conjecture that an individual's mathematical concept development progresses generally through the same stages as the historical development of the concepts. Students also read a vignette on the number zero and included in the opinion section of their ERMO summary whether children have a difficult time with the number zero. Students were given one week to post their ERMO summaries. They were not required to respond to any discussion questions and were not explicitly required to respond to one another's ERMO summaries. This ERMO, similar to Assignment 1, had a pedagogical component to it.

Students in Group 1 (F, L, P, G) each posted an ERMO summary, but also reacted to the statements made in the summaries. Many ideas relating to classroom experiences were shared within the group discussion. At one point Student G stated, "This is a great discussion…It is something I have not contemplated over much" and continued to share his views on resolving student confusion in the classroom. Another discussion was sparked by an ERMO summary that caused Student G to respond: "I was intrigued by your statement 'born into a base ten number system'…but I think the idea invites more exploration." This student then went on to cite many examples of other bases that students come in contact with on a daily basis.

In contrast, Group 2 (Q, I, O, K, E) had only one posting that was not simply an ERMO summary. In that message, which was coded as Integration, Student Q built upon a topic brought up in an ERMO summary by another student. The author of the ERMO summary did not respond to Student Q's posting, nor did anyone else in the group.

Content analysis results for this assignment are found in Table 8. The third highest number of Integration postings occurred during this assignment's discussion postings.

Assignment 9

The next Unit Three assignment asked students to investigate prime numbers. In the first half of the assignment students were asked to define prime numbers and prove that there are infinitely many primes, then to compare their work to Euclid's. The proof was embedded within the assignment unlike in Assignments 2 and 6 where the mathematical problems were the assignment. These tasks were to be completed within

four days. A posting by Dr. Brook explained his strategy for using historical

mathematical problems in the course:

> Every problem I have given you in this course is rooted in a famous historical
> problem that was challenging to solve. Furthermore, I have tried to emphasize that
> every historical problem has many related problems that can be simpler and
> useable in your classrooms. You have to search for these related problems and be
> creative. There is no book that will do this for you.

The students were asked to identify propositions from Euclid's Book IX that could be

useful for prompting their students to think more deeply about the mathematics they are

expected to learn or already know. Class members were also required to search the

Internet for unsolved problems involving primes and to discuss (in their assignment) the

problems their students could investigate with a calculator or online application.

In the last part of this assignment the instructor identified two driving forces

behind the progress of mathematics: 1) Humans are drawn to its unreasonable usefulness

and 2) Humans are drawn to its beautiful reasonableness. Students were asked to decide

which force drove the interest in the problems they located. They were given six days to

complete this half of the assignment. Students were asked to post each part of the

assignment by a certain due date; no specific discussion questions were provided. Overall

the assignment contained a diverse set of requirements when compared to the

assignments up until this point.

In Group 2 (I, O, K, E, Q), the first message was posted by Student Q was as

follows:

> Message 532
> I did some research and modified a few definitions of prime to arrive at this. Feel
> free to change or modify it.

> A number n in the set of integers is defined as prime if it cannot be expressed as a product of two separate factors, n=ab, where neither a nor b are the number 1 or -1.
> I am working on proving the infinite primes, but everything I use sounds too much like Euclid's proposition.

Initially, Student Q seems to assume that his group will work together, indicated by his willingness to share his progress and his statement "feel free to change or modify it." However, in the next posting Student I answered the questions posed by the instructor without any reference to Student Q. The rest of the group did the same. In answering the rest of the questions posed by the instructor for the assignment, Student Q followed the rest of the group and simply posted his responses.

The only group that held an authentic discussion for this assignment was Group 4 (A, D, N, and J). Students N and D initiated the discussion by making sure to answer all of the questions posed by the instructor. The students then had the following exchanges which led to other students joining the discussion as shown in the following thread excerpts:

> Message 586 (excerpt)
> I was thinking some more about [this] problem, and think that it is important for us as teachers to make sure we thoroughly define prime numbers to our students. …I like the wording written above, I think by Dan that the prime numbers are natural numbers that have exactly two factors, 1 and itself.
> Student N

> Message 590 (excerpt)
> I agree with you on the importance of providing clear definitions. When possible, exceptions should also be avoided. That's why I like the definition of prime numbers as natural numbers that have exactly two natural numbers. …
> Not much as been said here about Euclid's concept of unity. Do you think he regarded 1 as a number?
> Student D

Message 593
Would he consider it a unit of measure or 1 unit long? Good question. I do want to make a comment about natural numbers though. (Student describes workshop about real number system and varying definitions of natural numbers she had encountered)
Student J

Message 594
Student D: Forgot to give you an answer. I think he would consider it as a 1.
Student J

Message 600 (excerpt)
Interesting. I always thought natural numbers were called such because they were "natural" or occurred in nature. Unless you want to argue about a hole or something it doesn't seem like negative numbers are all that natural.
That being said I was pretty sure that natural numbers had to be positive integers and 0 while whole numbers were basically the same thing as integers.
Student A

Message 603
Student A: I certainly agree—negative numbers aren't all that natural. We educators go to some pretty great length to try to sell our students on negative numbers. I understand the students' skepticism.
Student D

Message 602
Student J: I think you made a good call. As far as I've ever been told the whole numbers include zero while the natural or counting numbers start at 1.
Some folks in these discussions have mentioned the fact that we start counting with 1 (not zero). Maybe that's a mistake… Then, as if to add insult to injury, we say that zero is not a "natural" number. No wonder zero has such a bad attitude! Not much has been said here about Euclid's concept of unity. Do you think he regarded 1 as a number?
Student D

Message 608
You pose a very interesting question. Did Euclid view 1 as a umber?? I am not sure how to answer that question, but my gut feeling is that yes he did, but I am not sure how to explain why I think that. I do know that if you look up PRME in the dictionary it defines it as a number divisible by only itself and unity (at least the dictionary I had at school today). I think it is interesting that it is not referred to as 1 even in this day and age. I would be interested to hear what the rest of you think on this, I guess I am just curious.
Student N

Message 599
By the definition of exactly two factors, 1 would not be prime, but -1 would. Just pointing that out, but I agree that natural numbers or positive has to be included in the definition. I put in mine that -3 would fit the definition, not to say that it's correct but to point out the deficiency in the definition I normally use. Being careful is very important.
Student A

The discussion continues with all four students participating in message exchanges.

Assignment 10

Assignment 10 was comprised of three readings. The first reading was based on the symbols used in mathematics and where those conventions come from. Students were asked to pick three symbols whose histories surprised them and conduct Internet research to find more information on each symbol. From the second reading, "Mathematics by Decree," students were to pick out two conventions that related to the mathematics taught in their grade band and then briefly explain how to justify each convention to their students. From the third reading on mathematical impossibilities people have believed through the years, students were to pick out two "impossibilities" that related to the mathematics they taught and explain how they would get their students to appreciate why humanity had such a hard time adjusting to the fact that they were, in fact, possible. The assignment instructions here were different than for the ERMOs in that reading summaries were not required. Instead students were only asked to respond to the questions. Students were given four days to post their responses to these questions.

The majority of postings in each group were coded as "required" as shown in Table 8. The students answered the questions posed by the instructor as instructed and individually, with no regard for one another's input. Only Group 4 (A, D, N, J) posted

messages that were not simply meeting requirements. The following exchange occurred

between Student's J and N:

> Message 680 (excerpt)
> I was wondering how you would explain the 0! and 1!
> Student J
>
> Message 681 (excerpt)
> This is a hard topic to explain, but my understanding of it is that you have to look at an alternative definition of factorials. For example, (student goes on to explain)…
> It is hard to type an explanation, but I found a pretty good one on the internet. Here is the link, I hope it helps. (link provided)
> Student N
>
> Message 682 (excerpt)
> Hi Student N
> I can follow what you are doing however what do you say to a student when he/she wants to substitute 0 in because that is what we are dong with all the other numbers (shows example).
> Isn't the n in the problem zero?
> Student J
>
> Message 683 (excerpt)
> I agree that this is a hard thinking to explain to a student, and I totally understand where the confusion comes from. I thin that I would explain to them that 0! Is a very special case and then go through the proof using 1! And solving for the 0!=1. This way the understand how to do factorials and also understand that 0! Is a SPECIAL case of factorials, and they also understand why.

> A similar exchange happened between Students A and D when Student A posed a

mathematical content question:

> Message 676 (excerpt)
> Along these lines with imaginary numbers also, why isn't there some kind of imaginary number set that gives us negative absolute values or is that of no mathematical value?
> Student A

Message 678
Student A: This may not be precisely what you're getting at but it is interesting how complex numbers have an "absolute" vector length on the complex plane.
Student D

Message 709
Student D: Thanks for that. That slipped my mind, but that [is] something at least. Funny things, those imaginary numbers. I get to start on them in 3-4.
Student A

Message 679
Student A: I too use the distance traveled idea to explain absolute value. (goes into more depth)
I have never considered absolute value of an imaginary number. That might be something interesting to look into!
Student N

Discussions such as those shown above from Group 4, did not occur in the other groups.

Assignment 11

The instructor noted that Assignment 11 would be light due to a major education conference taking place during this time in the semester. The assignment for the week was to read a chapter on Archimedes' proof that the pi of circumference was the same as the pi of area. Students were asked to explore whether there were any faults in the proof and to post their thoughts on the chapter and the proof within five days. Students up to this point had written their own proofs, but had not been asked to analyze an existing proof.

Group 1 (F, L, P, G), which focused on finding a fault in Archimedes proof, combined their postings in only one discussion thread when posting for this assignment. This group did not post thoughts on the chapter at all. Group 2 (I, O, K, E) did adhere to

that part of the task. Student I stated in the first posting of the group that the proof made

sense and that he did not see an error. Student I then stated in a second posting, "I just

noticed we're supposed to reflect on the chapter as well," and proceeded to do so. The

researcher noted that in this group, each individual person started his or her own thread

rather than posting as a group within a single thread. Student D, who was from a different

group, was the only student to respond to any postings in Group 2.

In Group 3 (B, C, M, and H) the students also used individual threads for their

postings. Student M did not post a message and the sole posting by Student C was as

follows:

> Message 703
> After reading the proof, I can't find where there is an error. It seems logical to
> me……..I will spend some more time on it to find out if it is wrong.

Student H was the only student in this group to post his or her thoughts on the chapter. In

response to Student H's posting, Student B presented a suggestion for the possible error

Dr. Brook identified in the proof they analyzed. Student H in turn responded to the

suggestion that same day, but the interaction ended there.

In Group 4 (A, D, N, J), the students posted their messages within a single thread.

The first posting by Student D read: "The Dunham reading is absolutely marvelous. I'll

have more to say in a future summary." Student D did not post a summary at any time.

The second and only posting by Student N read:

> Message 712
> I agree with Student D that this is a very interesting article. I have never actually
> seen the proof for the circle area formula, and it is not quite what I expected.
> As for finding any faults in the proof. I have not been very successful yet. I will
> keep looking, but I am interested to see what others have to say about it.

Overall student comments about the article did not grow in depth. The students, similarly to other groups, instead focused on critiquing the proof.

Table 8

Unit 3 Content Analysis Results

Category	A8 #	A8 %	A9 #	A9 %	A10 #	A10 %	A11 #	A11 %
Comment	4	6.15	3	4.92	2	4.88	3	5.66
Teaching presence	1	1.54	5	8.20	2	4.88	7	13.21
Triggering Event	1	1.54	0	0	1	2.44	0	0
Exploration	43	23	48	78.69	32	78.05	33	62.26
RP	66.15	53.49	37	77.08	28	68.29	10	30.30
Integration	16	24.62	5	8.20	4	9.76	10	18.87
Resolution	0	0	0	0	0	0	0	0

Assignment 12

The next unit commenced with Assignment 12, where students were asked to read a chapter on the history of algebra and then to: state a definition of algebra, state a definition of algebra that their students would give, explain the development of algebraic notation, and explain how their students relate to those stages in the development of their understanding of algebraic notation. This assignment, as with Assignment 10, did not require a summary of the reading; instead, responses to the questions posed by the instructor were the only requirement. Groups remained the same for this unit and students were given approximately one week for this assignment.

The only messages posted that were not a direct response to the requirements of the assignment occurred in Group 1 (F, L, P, G). Student P offered the following comment in her response to a statement made by Student L in her required posting:

> Message 798
> Also, in your statement about the equals sign, I see that all the time. I think there is the misconception that the equals sign isn't a balancing act, but a chain connecting a series of mathematical operations performed by the student.

Student D from Group 4 responded and asked for suggestions in helping students avoid this common misconception. Student P and Student L both offered suggestions. Thus, Student P made a connection to Student L's posting and made a comment from her own experience. Student D, who often visited other groups, looked for pedagogical solutions in addressing the topic thus pushing the discussion further.

Assignment 13

Students were asked to first come up with a solution to a problem from Fibonacci's book *Liber Abbaci* (1202 AD), then to give their students the same problem and report on their solution processes noting the use of Rhetorical, Syncopated, or Symbolic representations in their reasoning. Solutions were to be posted within four days. Once solutions were posted students were given two days of discussion to compare their solutions to those of their peers and to the student solutions. Students did not post actual solutions from their students; rather they described in general the results. Additional assignment requirements given by Dr. Brook are described in Assignment 14.

The majority of the postings for each group were categorized as "required" (see Table 9). Groups 2 (I, O, K, E) and 3 (B, C, M, H) each did have one additional posting

where someone acknowledged that group members were solving the problem in the same way. Groups 1 (F, L, P, G) and 4 (A, D, N, J) posted multiple messages on other topics beyond the required postings.

Assignment 14

The continuation of Dr. Brook's instructions (separated as Assignment 14 by the researcher) required the students to read an article on classical word problems that have historical importance and to choose one of the problems and write a brief report on its history. In addition, the students were asked to find and share Web sites with other historical word or algebra problems that related to their students' mathematics curricula, and to share the types of problems found. Students were given one week to complete this assignment. The due dates for Assignments 13 and 14 overlapped by one week.

Nearly all of the postings associated with this assignment were coded as "required" as shown in Table 9. In one attempt at discussion, Student Q asked a fellow student: "Student O, Did you get 4/7, 2/7, and 1/7?" Student O did not respond. Student K also posed a question to Student O: "Your link did not work. Is there another way to access this site?" Student O again did not respond.

Assignment 15

An addition was made to Assignment 13 on the day that problem solutions were due. A follow-up task given by Dr. Brook asked the students to analyze the solution process of a fictional student and post an explanation of the solution along with a comparison between the student's approach and their own. Thus Assignments 13, 14, and

15 were connected to the same core content. Class members were given two days to complete this follow-up task.

Again, analysis of the postings from this assignment found that nearly all were "required" as shown in Table 9. Students overall posted an explanation of how the fictional student carried out the solution process, but did not expand further. Student C did not post to his group at all for this assignment. Student D posted to Group 3 (B, C, M, H), in response to a question posted by Student B: "Did anyone investigate further?" Student D stated that she did investigate further and provided an explanation of what she found. This is the only example in this assignment where students went beyond the minimum requirements of the instructions.

Assignment 16

The last assignment in Unit Four had two parts. In the first part, the students chose three "capsules" from their course text that addressed topics related to numbers, numerals, and computation. They were to describe each capsule in terms of what their students could learn by studying the history and mathematics contained in them. The three examples were to be posted in less than two days. Next students were to choose one of the capsule topics and a lesson plan from their classroom that related to the topic. The lesson plan was to be re-written so that it incorporated the history of the topic. The students were told by Dr. Brook, "Your lesson plan should not be a lesson on history. Instead, it should be a lesson plan on a mathematical topic in which history is embedded." This assignment incorporated a pedagogical tool that the students were accustomed to using on a daily basis in their classrooms. Rather than students "making

up" a lesson plan they were modifying what existed in their resources. Students were

given five days to complete the lesson plan.

Once the due date arrived, students were told to post their lesson plans and react

to the plans in their group. Specifically, they were asked to answer the following: 1) Is

the lesson clear enough and detailed enough that you would be able to use it if you were

called on to be a substitute teacher in the author's class and received the lesson the day

before teaching it? and 2) How would you modify the lesson to fit classrooms in which

you teach or have taught?

Results of content analysis (Table 9) indicate that student postings were varied

and more numerous for this assignment, as shown by the 40 non-required Exploration

postings as well as the 18 Integration postings (the second highest number among all

assignments). The quality of individual postings varied widely within the same phase of

the coding protocol, as shown in the following two postings both coded as Integration:

> Message 928 (excerpt)
> Student P—I really like the incorporation of the Bridges of Koenigsberg into your lesson including he warm information. I think when you introduce the factorials, it would be good to include some background on 0 factorial—you could maybe slip in a bit of zero history while doing it.
> Student L
>
> Message 967 (excerpt)
> Hey there…
> I read over your lesson plan and the comments already posted.
> I think you did a great job. I love the bridges problem and having your students actually attempt it.
> On reading the comments I kind of disagree with adding in a history of zero. Instead it would be nice to again connect to the bridges problem that you opened with. You had your students look at how many ways the bridge problem and the modified bridge problem can be completed and then you introduce the idea of permutations which is good. If I were a student in your class my question at the

end would be, "How do we calculate the number of bridge paths using combinatorics? Can we? Why or why not?"
I feel like addressing these questions and more firmly connecting your opening activity with the mathematics learned is more important than including additional historical material. Just my opinion…
Student G

In Message 928, Student L's response to Student P's lesson plan was vague and did not

justify why including background on 0! or the history of zero would be beneficial.

Student G, on the other hand, clearly explained why he would not include the history of

zero. However, both messages meet the criteria for Integration.

Table 9

Unit 4 Content Analysis Results

Category	A12 #	A12 %	A13 #	A13 %	A14 #	A14 %	A15 #	A15 %	A16 #	A16 %
Comment	1	4.76	1	2.27	4	12.9	0	0	12	.12
Teaching presence	1	4.76	0	0	0	0	0	0	0	0
Triggering Event	0	0	0	0	0	0	0	0	0	0
Exploration	18	85.71	35	79.55	27	87.10	16	94.12	69	.69
RP	15	83.33	24	68.57	25	92.59	14	87.5	29	42.03
Integration	1	4.76	8	18.18	0	0	1	5.88	18	.18
Resolution	0	0	0	0	0	0	0	0	1	1

In Group 3 (B, C, M, H) two students posted their lesson plans by the due date. One

student did not post a lesson plan at all, stating:

Hi all. I know I have been a COMPLETE slacker on Unit 4 here. Just as [we were] starting [to] use the textbook, I found mine missing! I e-mailed Dr. Brook, but thought you might want to know as well. I now have the text and will be hard at work playing catch (up) again.
Cheers—Student M

Student C posted his lesson plan to this group discussion nine days after the assignment due date. This was typical of this particular student and a few others in the class.

Assignment 17

Assignment 17 began Unit 5, where students were asked to explore non-Euclidean geometry using an applet on the Internet. This was the second time students were asked to use an online applet for exploration. Students were to investigate and discuss the construction of a square and the perpendicular bisectors of the sides of a triangle. Thoughts and questions were to be posted within four days. This was the first assignment where students were not assigned to groups; instead, the whole class discussed the assignment together.

In the first two postings, Students K and O were not afraid to admit their faults:

Message 956 (excerpt)
YEAH!!!! I get to be the first to post. Usually I am the last one and very late.
Student K

Message 962 (excerpt)
YEAH FOR ME! I'm actually not late on an assignment! I have to disagree with student K, I'm the last one in our group to post. For once we're not behind Student K!:) (At least for this class)
Student O

The two students made it clear they were aware that they rarely posted on time, but did not seem to indicate regret or a desire to change their habits.

At the end of one of his postings in the whole-group discussion, Student Q asked: "Are there other methods of construction in Non-Euclidean Geometry where the sides of the construction are convex and not concave? In other words is there a way of having the lines appear as if I am looking at the latitude and longitude lines on the globe?" The student did not get a response from anyone. Students generally posted their responses to the instructor's questions as required postings and other than that, posted only technical comments on how to use the applet. Student L was the only student to post any other thoughts. Thus a collaborative group discussion did not occur.

Once most of the students had responded to the initial assignment questions, the instructor interjected a new question: "What is another way to define a square in Euclidean geometry that is 'equivalent' to Euclid's definition within Euclidean Geometry and yet can be constructed in Non-Euclid???" This question was posed within the discussion, not during the original assignment requirements, thus it was found within the Assignment 17 discussion rather than in the assignment folder. Just over half the class (Students I, Q, B, L, N, J, G, M, and H) responded to this new question. Eight of the ten Integration postings that occurred during this discussion were in response to the new question posed by the instructor.

Assignment 18

Students were asked to complete a lesson plan with nearly the same requirements as in Assignment 16. This time they examined textbook capsules on a variety of topics related to geometry, then went through the same steps: choose three to describe and then re-write a lesson plan using one of the topics. Students were given one week to post the

lesson plan. They continued to post to the same folder as a whole group. The students were asked to critique the lesson plans of others "in their group" in the assignment requirements, but small groups were not formed for this assignment. Also the instructor did not reiterate that students should critique one another's postings.

As shown in Table 10, students posted only the minimal requirements. All postings were coded as Exploration and only four of these postings were not required.

Assignment 19

The last unit (Unit 6) was shortened due to lack of time remaining at the end of the semester. The unit's basis was the history of trigonometry. Students were asked to consult their textbook and at least one online source and write a one-page answer to two questions: 1) What is the history of our methods (degree and radian) of measuring angles? and 2) What is the history of the cotangent and tangent quantities…what did these ideas have to do with the ancient Egyptians, and what did they have to do with sundials? A third question asked students to investigate similar right triangles using the non-Euclidean applet. Dr. Brook specified that students were to work on their own and post results within five days. He also created a discussion area to share ideas and questions on the assignment. Results of content analysis in Table 10 verify that the majority of messages were coded as Exploration and were required.

Table 10

Units 5 and 6 Content Analysis Results

Category	A17 Count	A17 Percent	A18 Count	A18 Percent	A19 Count	A19 Percent
Comment	9	16.67	0	0	3	12.5
Teaching presence	2	3.70	1	4.17	2	8.33
Triggering Event	0	0	0	0	0	0
Exploration	33	61.11	23	95.83	19	79.17
RP	15	45.45	19	82.61	15	78.95
Integration	10	18.52	0	0	0	0
Resolution	0	0	0	0	0	0

Development of Task Typology

Instructor's Perception of Task Types

Oliver and Herrington (2001) noted that learning tasks are viewed as the "pivotal elements in the design process for online learning settings that are designed to support knowledge construction" (p. 25). They stated "the intention of the learning task is to provide the learner with some context and purpose for the information that is presented as the course content" (p. 31). As noted earlier, the tasks assigned to students in the Fall 2007 MATH 500 course were designed solely by the instructor. The instructor's views of the learning tasks he commonly implements in online courses were compared against his students' perceptions of the task types they were exposed to in MATH 500 and analyzed

for common themes. As noted in the review of literature, Ron Oliver and his colleagues are one of the few groups to have extensively studied online pedagogy, and one of even fewer to have produced a task typology. The tasks described by Dr. Brook and the MATH 500 students were also compared to the task types described by Oliver and his colleagues.

During an interview with Dr. Brook, the researcher asked about the usual types of tasks he implements in his online classes. He spoke of three big "genres" (his word) which included: 1) readings, 2) mathematical problems, and 3) realistic learning. Each will be discussed further in the paragraphs that follow.

First and foremost, Dr. Brook wanted to make it clear that there are no lectures in his online classes. Instead, through readings that are purposefully chosen to be somewhat "off-center," he lectures through the words of others. The intent is to choose articles that provoke the students to be critical, thus getting them to think about whether or not they should agree with the author. This is done in both Dr. Brook's pedagogical and content-based mathematics classes, although he notes that in the pure math setting it is somewhat more difficult to find readings that are "off-center." He feels this makes it more difficult in the pure math setting to provoke the kind of gut-level reaction or reflection attainable in the pedagogical setting. As the instructor he does not want to be the person projecting "Here's my answer, here's my synthesis, and you should believe it because I'm the teacher." Instead, Dr. Brook wants the students to come up with the "synthesis and big ideas" so that he is more of a facilitator and the students are the synthesizers. This strategy of Dr. Brook's represents a student-centered learning approach to education

where "learners play more prominent roles in their learning" rather than an educational approach "characterized by teacher-led content development and mass lectures" (Oliver, 1998, p.2).

ERMO summaries and paper conferences fall under the "readings" task genre. Along with completing assigned readings, students are sometimes asked to construct what Dr. Brook refers to as an "ERMO summary" where students must "Earn the Right to My Opinion." Students achieve this by accurately and objectively summarizing the main points of the reading, then following this analysis with a paragraph of reflection composed of their opinions and reactions regarding the reading. Finally, students are asked to critique their peers' summaries and identify something from the work of others that would have made their own summary better. This sequence of analysis and comparison results in assessment of self, of peers, and of outside source material. Another example of Dr. Brook's "reading" task type is the paper conference. Here students write a paper on some assigned topic and post the paper to a discussion. They then read one another's work and write a one page critique. In return, the writer has to take into account the critiques and revise his or her paper for final submission to the instructor. Dr. Brook feels this develops the students' critical thinking and evaluation skills. This task type has similar goals to Oliver's "inquiry tasks," where the learner seeks to gather specific information or meaning from the resources that are presented (Oliver & Herrington, 2001, p. 31). These tasks are typical of online learning settings.

Mathematical problems are another type of task commonly implemented by Dr. Brook. The following quote sums up his view about implementing mathematical problems in a course with an audience of practicing teachers:

> I really think all these teachers in our program are math teachers because they somehow like mathematics and they've never had the chance in recent months or years to do any mathematics. They teach what they have in their textbooks and schools but they don't ever do any mathematics, or are challenged to do mathematics. It's difficult for them to go back; but they thrive on it ultimately. In that sense it's like Gold's Gym – I'm gonna get them back in mathematical shape.

The problems Dr. Brook generally chooses to pose are often unique, unfamiliar to his students, and in his view much more challenging than most standard textbook problems. His intention is to "make them really think about the math that they teach, and reflect on that math they teach…partly by challenging them in their own understanding of that math." His goal in selecting and posing mathematical problems is to get the students to think deeply about what they teach and what they think they know. In problem-based learning settings, "Problems do not encourage simple, lower level solutions but demand that students pursue new knowledge through the process of solving the problem" (Oliver, 1998, p.412). Because Dr. Brook intentionally chooses problems that require students to engage cognitively and to demonstrate higher-order learning skills, this genre of tasks relates directly to the problem-solving tasks described by Oliver and Herrington (2001) which provides a setting for learners that supports knowledge construction.

The last genre Dr. Brook spoke of was "realistic learning" where the students connect their knowledge to the real word. "Living laboratories" compose a subset of this genre, where students use their own classrooms as a laboratory to learn more about the topics at hand. The objective of this type of activity is "to let the teachers face the

phenomenon of the teaching/learning situation in the context of the course they're taking.
It puts real data on the table, real students on the table, real work, and the teachers then
get to grapple with what that evidence tells them about the phenomenon they're
studying." Dr. Brook gave an example of a living laboratory activity from a pedagogy-
based course he taught the previous spring:

> I put them in teams of four and had them conduct a mini state assessment on
> somebody's class and go through all the motions of the main things you would
> have to do which would be: construct the test from the standards, guarantee the
> alignment of the test, give it out to the schools, grade it, code it (which is for
> proficiency which is another huge area of disagreement) and then come back and
> slap the school down and think about all the different layers of what goes on there
> and what good it does to anybody.

The core concept in this genre is that teachers make a connection to their own
practice on a realistic level, which closely parallels the "authentic tasks" described by
Oliver and Herrington (2001). "Authentic tasks are tasks that are similar to those that are
faced in real-life" (Oliver & Herrington, 2001, p. 32). These tasks have real-world
relevance, are complex and ill-defined, and do not have a right or wrong solution.
Authentic tasks form the basis for student learning in contemporary approaches to
instructional design (Oliver & Herrington, 2001, p. 32). Also in this genre, Dr. Brook
refers to the availability of online resources. In his opinion, the Internet enables up-to-
date coursework and materials because of the ready availability of readings, applets,
videos, and other resources. These are constantly updated making the materials more
realistic compared to using print resources that were written 10-20 years ago.

Oliver and Herrington (2001) described two instructional design approaches in
their guide to teaching and learning online. *Content-based instructional design* has

content delivery at the center of teaching and learning. This content takes the form of lectures and pages of text, and serves as the focus of learning. *Task-based learning*, by contrast, focuses on how to use that content meaningfully. Learners do not simply read text without purpose and listen to lectures passively. Instead they are actively engaged with the material in some way. Students learn how to use and apply the content rather than memorizing the information. Dr. Brook's beliefs and practices regarding online course design, and his encouragement of active student engagement with readings and tasks, identifies his style as a task-based approach to learning.

Students' Perceptions of Task Types

The first question on the survey given to students following completion of the Fall 2007 online course asked them to self-identify the task genres used in MATH 500.

> Suppose a friend interested in taking [this course] next year asked, "What did you do in the class?" forcing you to think back to the different tasks and assignments you completed. Create a generalized list for this person that categorizes these tasks according to their similar features and expectations. Avoid naming specific assignments (e.g., the Dido problem) and instead describe the types of tasks you encountered. For example, you might identify a category of tasks called "reading summaries."

The intention of this question was to ascertain students' perceptions of the main types of tasks assigned in MATH 500. Eleven students responded to this particular question; two left it blank. The majority of the responses identified the following four types of tasks: readings/summaries, math problems/proofs, lesson plans, and book report. The first two task types, "readings/summaries" and "math problems/proofs," which were identified by ten of the students, were task types that directly aligned with Dr. Brook's description of the major task genres he employs in his online classes. The response "lesson plans," was

mentioned by nine students. This task type arose from a realistic learning experience in which the students were asked to create actual lesson plans for use in their classroom using information gained from course activities. Thus, the lesson plan can be characterized as a realistic learning task type as described by Dr. Brook.

As a final project for the class, students were asked to do a book report. In this assignment, each student chose and read a historical mathematics novel or work, provided an overview of the book, and discussed an idea or two that piqued the student's interest. Students were then asked to explore connections between the book and the K-12 classroom in terms of an appropriate class setting for the book and an activity that could be drawn from the text. Although this was a stand-alone task in the course, eight students found it compelling enough (perhaps because it was the final project) to classify it as a task type.

Three other task types were mentioned by four students or less: discussions/group work, historical research/investigations, and computer explorations/Web searches. Because group work serves as a strategy for completing a task rather than a task in its own right, and because discussions are a component of virtually every task in the course, they were not recognized as independent task types, but rather as strategies used to complete a task. The other two task types, "historical research/investigations" and "computer explorations/Web searches" are discussed in the following section.

<u>Relating Assignments to Task Types</u>

Taking into account commonalities between the online task types described by the course instructor and the students' perceptions of the task types they encountered, the

researcher identified three main task types: 1) readings, 2) mathematical problems, and 3) realistic learning. The nineteen researcher-defined assignments were then analyzed in terms of the task types described by both the instructor and the students.

In order to assess whether the 19 assignments identified by the researcher were representative of the task types described by the instructor and students, each assignment was evaluated by the researcher and assigned to one or more task types depending on the requirements of the assignment. The assignments corresponding to a single task type were then re-evaluated and compared against each other to ensure that each assignment had characteristics that justified its categorization to that particular task type. Among the three main tasks types—readings, problems, and realistic learning—there was no overlap of assignments, but some assignments did correlate to the "historical research/investigations" and "computer explorations/Web searches" task types as well as to one of the three main task types. For instance, the Trisection Problem assignment had a component that asked students to find a Web site that told the history of the problem. This required an Internet search and involved historical research into the problem, thus the assignment was coded under "problems," "historical research," and "computer explorations." Each assignment (6, 19, 9, and 14) that was categorized under "historical research/investigation" was also coded under "computer exploration/Web search." The researcher determined that computer explorations and Web searches were used as a strategy for completing the historical research/investigations. Assignments 17 and 7 were also viewed as requiring computer exploration since they used an applet contained on the computer. But again, the computer was used as a tool for completing the assigned

mathematics problem in each case. The category computer "exploration/Web search" was deemed a strategy or tool for completing tasks and not a separate task type.

At this point the researcher analyzed assignments 6, 19, 9, and 14 to determine whether these tasks should be categorized as "historical research/investigations" or categorized as one of the other three task types. Assignment 6, which required students to work on the Trisection Problem, involved 106 messages with approximately 17 related to the Web sites and classroom applications. Since the majority of the postings were attributable to the trisection problem itself, this assignment was categorized as a "mathematical problem" task type. Assignment 19 required students to consult their textbook and an online source to write a one-page response to two questions and also to use an applet for non-Euclidean geometry to research similar triangles. The instructor acknowledged that the students were given more freedom than usual to complete this assignment, thus it was not typical of others. The students answered the posed questions as a required assignment and posted their individual answers in the same way that the ERMO assignments were addressed. Thus Assignment 19 was ultimately categorized as a "reading."

The first half of both Assignment 9 and Assignment 13 called for students to complete problem solutions and compare them to other solutions. Assignment 13 additionally required the students in MATH 500 to give the same problem to the students in their own classrooms (an example of a "living laboratory" activity). In the second half of Assignments 9 and 13, students looked at historically related problems using the Internet and other reading resources. The researcher kept all aspects of assignment 9 as

one assignment. Because assignment 13 had the realistic learning activity in which

students' students were involved, he researcher considered this a substantially different

activity, and separated it into two assignments. Thus assignment 9 included the problem

solution and historically related problems, assignment 13 included the problem solution

by both students in MATH 500 and their students, and assignment 14 was a stand-alone

assignment with historically related problems. The mathematical discussion in

Assignment 13 produced a variety of postings, but Assignment 14 produced only two

messages that were not the result of a "required posting." In analyzing the postings for

Assignment 9, similar results were found: the non-required postings were due to the

mathematics problem, while the portion that used the Internet produced only messages

classified as "required postings." Thus, Assignments 9 and 13 were both categorized as

task type "mathematical problem" and noted as having additional requirements.

The book report, which was a final project for the course, had no discussion or group

interactions as a requirement. The purposes of this study were to thoroughly analyze the

discussions produced by the tasks, thus the book report project was not acknowledged by

the researcher as a separate task to be analyzed. In summary, the task types that were

recognized for analysis, taking into consideration a combination of instructor perceptions,

student perceptions, and researcher-identified assignments, were "readings," "problems,"

and "realistic learning." Table 11 summarizes the categorization of the nineteen

assignments in MATH 500 and briefly describes the nature of the assignments grouped

under each task type.

Table 11

Assignments Categorized by Task Type

Task Type	Assignments	Description
Readings	1,4,8	ERMO
	3	Biography
	10,12	Readings/applications to classroom
	19	Readings from text/online source
Problems	2,6	Historical math problem – higher cognitive demand
	9,13,14	Historical math problem –lower cognitive demand
	7,17	Problem exploration based on Web applets
	11,15	Analyze a given proof
Realistic	16,18	Lesson plan
	5	Discussion of classroom uses for math history
	13	Fibonacci to problem given to students' students

Analysis of Cognitive Presence by Task Type

Reading Task Type

       Seven of the nineteen assignments were classified as readings by the researcher;

these required both reading and writing as part of the assignment. The assignments were

further grouped within the reading task type according to specific similarities the

assignments shared. Assignments 1, 4, and 8 were each clearly identified as ERMO

summaries by the instructor. Assignments 10 and 12 had required readings and

corresponding questions for the students to answer in response to the readings. These

were not specifically classified as ERMOs by the instructor. Parts of the questions asked

the students to consider their own classrooms in their response. Assignment 3, the

biography, and Assignment 19, which involved outside resources, were each considered

unique. Table 12 summarizes the results of coding the messages from each reading

assignment. The number of messages for each coding category is presented along with

the total number of posted messages for each assignment. Next, the total number of

messages coded to the four phases of the Practical Inquiry Model is presented. Lastly the

number of Exploration postings that were recorded as "required postings" is noted and

the total number of messages coded to the PIM phases is listed again, this time excluding

the required postings. Shading separates the sub-groupings described above.

       The ERMO summaries in Assignments 1 and 8 had the highest number of

postings and highest number of Integration phase postings. The ERMO summary of

Assignment 4 had the fourth highest number of postings and the third highest number of

Table 12

Coding Results For "Reading" Task Type

Category	A1	A4	A8	A3	A10	A12	A19
Triggering Event (TE)	0	0	1	0	1	0	0
Exploration (EX)	38	21	43	20	32	18	19
Integration (IN)	13	8	16	1	4	1	0
Resolution (RE)	2	0	0	2	0	0	0
Comment (CO)	3	9	4	7	2	1	3
Teacher Presence (TP)	3	1	1	6	2	1	2
TOTAL MESSAGES	59	39	65	36	41	21	24
Total coded TE,EX,IN,RE	53	29	60	23	37	19	19
Required Posting (RP)	17	17	23	17	28	15	15
Non-required TE,EX,IN,RE	36	12	37	6	9	4	4

Integration phase postings. The other reading tasks resulted in far fewer postings coded as Integration. Recall that the researcher coded messages that were posted in response to assignment instructions as Exploration, but also noted that they were "required postings." In the last row of Table 12 it can be seen that Assignments 1 and 8 had the highest number of non-required postings coded to phases of the Practical Inquiry Model. There was not a high incidence of resolution in this task type. Assignment 1, an ERMO summary, and Assignment 3, the biography, were the only assignments which produced messages in the Resolution phase.

<u>Problem Task Type</u>

Nine of the nineteen assignments were classified as problems. These assignments were again grouped more specifically according to similar characteristics of the assignments. Assignments 2 and 6 required that students work on a historical mathematics problem (the problem of Dido for Assignment 2 and the trisection problem for Assignment 6) and then describe a part of the problem that could be given to their students. The researcher considered these problems to be of high cognitive demand and open-ended in terms of the structure. Assignment 9 and Assignments 13 and 14 combined

Table 13

Coding Results for "Problem" Task Type

Category	A2	A6	A9	A13	A14	A7	A17	A11	A15
Triggering Event (TE)	4	0	0	0	0	0	0	0	0
Exploration (EX)	65	62	48	35	27	17	33	33	16
Integration (IN)	26	16	5	8	0	7	10	10	1
Resolution (RE)	15	6	0	0	0	1	0	0	0
Comment (CO)	16	6	3	1	4	4	9	3	0
Teacher Presence (TP)	20	15	5	0	0	2	2	7	0
TOTAL	146	105	61	44	31	31	54	53	17
Total coded TE,EX,IN,RE	110	84	53	43	27	25	43	43	17
Required Posting (RP)	0	1	37	24	25	0	15	10	14
Non-required TE,EX,IN,RE	110	83	16	19	2	25	28	33	3

each contained a problem for students to work on followed by questions about similar historical problems. The difficulty level of these problems was slightly lower than the

problems in Assignments 2 and 6. Assignments 7 and 17 each required the use of an applet to explore mathematical questions. Finally, Assignments 11 and 15 required the students to analyze a problem solution or proof that was already completed.

Assignments 2 and 6 resulted in the highest number of postings both with and without required postings included. These assignments also resulted in the highest number of postings coded as Integration and coded as Resolution. Three of the 15 resolution postings from Assignment 2 were considered "not forced." In other words, the postings were not in direct response to the assignment instructions. All six postings coded as Resolution in Assignment 6 were a direct result of the assignment instructions. Teacher Presence was notably higher for Assignments 2 and 6 than for any of the other problem tasks.

Assignment 14, as described previously, was the second half of Assignment 13, and Assignment 15 was a follow-up task to Assignment 13. Each of these sub-components had considerably lower non-required postings, one Integration posting, and zero Resolution postings. Since they were part of a "larger" assignment, perhaps looking at them as stand-alone assignments does not capture the entire picture of what is happening.

Assignments 17 and 11 had the second highest number of postings that were coded as Integration and the second highest number of non-required postings that were coded to the Practical Inquiry Model phases. Assignment 17 explored non-Euclidean geometry with an applet while in Assignment 11 students analyzed Archimedes' proof that the pi of circumference is the same as the pi of area. Assignments 9, 13, and 7 had

the third highest number of postings coded as Integration and the third highest number of

postings that were coded into the PIM phases when required postings were omitted.

Realistic Learning Task Type

Three of the nineteen assignments were classified as realistic learning task types.

Assignments 16 and 18 were each lesson plans with nearly identical assignment

requirements. The notable difference in Assignment 18 was that although students were

initially told to critique their groups' lesson plans, there were no groups assigned.

Assignment 5 was a discussion that related directly to the classroom practices of the class

members. Assignment 13 had realistic learning embedded within it, where the students

Table 14

Coding Results for "Realistic Learning" Task Type

Category	A16	A18	A5	A13
Triggering Event (TE)	0	0	0	0
Exploration (EX)	69	23	12	35
Integration (IN)	18	0	11	8
Resolution (RE)	1	0	1	0
Comment (CO)	12	0	1	1
Teacher Presence (TP)	0	1	0	0
TOTAL	100	24	25	44
Total coded TE,EX,IN,RE	88	23	24	43
Required Posting (RP)	29	19	0	24
Non-required Posting	59	4	24	19

were asked to give their own students the Fibonacci problem to solve. Thus Assignment 13 is represented as a Mathematical Problem task type and also below as a Realistic Learning task type.

Assignments 16 and 5 both had a high number of postings coded to the Integration phase of the PIM. Each also had one posting coded as Resolution. Assignment 1 had the highest number of postings both with and without required postings included. Assignment 18 had 0 integration postings and 0 resolution postings. The assignment resulted in the students essentially posting their required assignments with no meaningful evidence of cognitive presence.

Percentage of Task Types Coded IN and RE

Table 15 summarizes the number (in parentheses) and percentage of postings that were coded as Integration and Resolution for each assignment. Percentages are summarized in three ways: 1) as a percentage of the total number of postings for an assignment, 2) as a percentage of only those postings coded to the four phases of the Practical Inquiry Model, and 3) as a percentage of the postings coded to the Practical Inquiry Model that do not include required postings.

Table 15

Integration and Resolution Counts and Percentages

Assignment	% of total postings		% of PIM postings		% of PIM (no RP)	
	IN	RE	IN	RE	IN	RE
			Readings			
1 (ERMO)	22.03 (13)	3.39 (2)	24.53	3.77	36.11	5.56
4 (ERMO)	20.51 (8)	0.00 (0)	27.59	0.00	66.67	0.00
8 (ERMO)	24.62 (16)	0.00 (0)	26.67	0.00	43.24	0.00
3 (bio)	2.78 (1)	5.56 (2)	4.35	8.70	16.67	33.33
10 (reading)	9.76 (4)	0.00 (0)	10.81	0.00	44.44	0.00
12 (reading)	4.76 (1)	0.00 (0)	5.26	0.00	25.00	0.00
19 (trig)	0.00 (0)	0.00 (0)	0.00	0.00	0.00	0.00
			Problems			
2 (Dido)	17.81 (26)	10.27 (15)	23.64	13.64	23.64	13.64
6 (trisection)	15.24 (16)	5.71 (6)	19.05	7.14	19.28	7.23
9 (primes)	8.20 (5)	0.00 (0)	9.43	0.00	31.25	0.00
13 (Fib 1)	18.18 (8)	0.00 (0)	18.60	0.00	42.11	0.00
14 (Fib 2)	0.00 (0)	0.00 (0)	0.00	0.00	0.00	0.00
7 (applet)	22.58 (7)	3.23 (1)	28.00	4.00	28.00	4.00
17 (applet)	18.52 (10)	0.00 (0)	23.26	0.00	35.71	0.00
11 (proof)	18.87 (10)	0.00 (0)	23.26	0.00	30.30	0.00
15 (proof)	5.88 (1)	0.00 (0)	5.88	0.00	33.33	0.00
			Realistic Learning			
16 (lesson)	18.00 (18)	1.00 (1)	20.45	1.14	30.51	1.69
18 (lesson)	0.00 (0)	0.00 (0)	0.00	0.00	0.00	0.00
5 (discuss)	44.00 (11)	4.00 (1)	45.83	4.17	45.83	4.17

The most significant information is found in the last two columns of Table 15, which displays percentages of non-required postings that fit the four phases of the Practical inquiry Model at the Integration and Resolution phases. All three task types employed by the instructor produced integration activity, with three reading assignments measuring integration messages at over 40%. One problem task and one realistic learning task produced a similarly high proportion of Integration phase messages. When comparing the task types to one another it can be seen that each task type has a wide range of Integration postings, both in terms of number of messages and percentage of messages. For instance, for the Reading task type, counts range from 0 to 16 and percentages range from 0 to 44.44%. Resolution postings were rare in the course for each task type. The Problem of Dido from the Mathematical Problem task type was the only assignment with a high number of Resolution postings when compared to the other assignments. The relationship of the task types to the Practical Inquiry Model phases will be discussed in Chapter 5.

Assignments Displaying Higher Order Learning

Figure 8 summarizes the number of postings that were coded to each phase of the Practical Inquiry Model for each of the nineteen assignments. Required postings that were coded as Exploration were omitted for the Exploration category represented by EX-RP. Assignments 2 and 6 had the highest number of postings coded as Exploration relative to the other assignments. Assignment 2, a problem task type, had the highest number of Integration postings at 26 messages. Assignment 16 had eighteen postings coded as Integration, and Assignments 8 and 6 had sixteen postings coded as Integration.

It is worth noting that the three assignments (2, 16, and 8) with the highest number of

Integration postings fell under different task types as noted in Table 11.
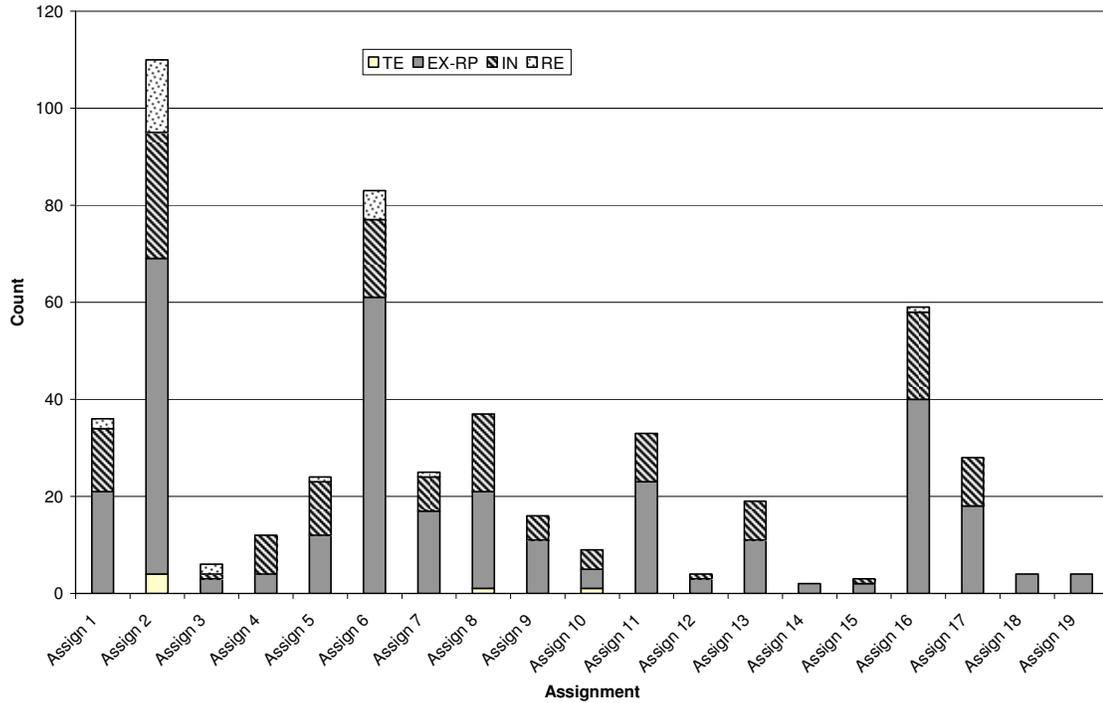
Figure 8. Number of messages coded to each PIM phase for each assignment.

Student Perceptions of Higher-Order Tasks

Four questions contained on the post-course survey were open-ended questions

that asked the students to reflect upon and analyze the types of tasks they encountered in

MATH 500 in reference to the actions they engaged in with the tasks. The questions were

designed based on the indicators of the cognitive presence coding protocol in order to

indirectly assess which tasks students perceived as encouraging the four phases of the

PIM. Two other open-ended questions sought student perceptions regarding which tasks

were most personally engaging and motivating and which tasks resulted in rich discussions.

The first question assessed student perceptions of the Exploration phase of the PIM. They were asked: "Which task(s) caused you to brainstorm and exchange information with your peers in order to make sense of the material addressed by the task at hand? Briefly explain how/why." Nearly every student answered the question in some form of the statement "math problems and proofs." Three people specifically referred to the problem of Dido from Assignment 2, and one person specifically referred to the trisection problem from Assignment 6. The Dido problem and trisection problem had the highest number of Exploration postings overall when required postings were left out. Student D stated "all of the tasks" and Student I said, "I really can't think of anything. While most tasks involved some discussion/interaction it seemed forced, like I was doing it just because I had to. I noticed that other groups had much more interaction and wish we could've switched up groups more. That might have spurred me to be more social." Overall, student perceptions of which tasks resulted in Exploration postings coincided with the content analysis results.

Students were then asked two questions that indirectly assessed which tasks they perceived to encourage Integration. The first question asked students: "Which task(s) caused you to make connections between ideas presented and synthesize the information you encountered in order to create new understandings of the course material/topics? Briefly explain how/why." The twelve student responses to this question were evenly divided between problems, readings, lesson plans, and "all tasks." Students were also

asked: "Which task(s) allowed you to develop and justify solutions, hypotheses, or beliefs? Briefly explain how/why." Mathematics problems and proofs were the common responses of eight of the twelve students that responded to the question. Student D responded "all tasks" once again, Student N talked about homework that could infer the problems, and Student P referred to readings. Student G did not indicate a specific task and instead responded: "This sometimes occurred in group discussions, but not that often."

Content analysis supported the varied student responses to the questions related to Integration. The three assignments with the highest number of Integration postings were each associated with a different task type (Reading, Mathematical Problem, Realistic Learning). Students were divided on the tasks that led to them making connections from ideas presented, but were more unified on the tasks that led to development of solutions and hypotheses. This is possibly due to the fact that mathematical problems are linked to the terms "solutions" and "hypotheses."

To assess student perceptions of the tasks where resolution occurred, they were asked the following question: "Which task(s) allowed you to discover new ideas that you could apply to your teaching practice? Briefly describe how/why." Four students identified the readings, three the lesson plans, and three the problems. Student D again responded "all tasks," Student L described the newness of the class topics overall, and Student A described his current implementation of history into the classroom. Students may have identified differently with varying tasks according to their teaching style and the content they were currently teaching. Postings were coded most frequently as

Resolution in Assignments 2 and 6, which were both problem task types, although overall resolution did not occur frequently in the course. This is not surprising since both of these assignments asked the students to identify a part of the problem that they could use in their classroom and discuss its application.

The next open-ended question, "Which tasks did you find most personally engaging and motivating, and why?" resulted in nine of the thirteen people referring to the mathematics problems and proofs. Four of these responses specifically referenced the Problem of Dido. Students N and P found the lesson plans were most engaging and motivating because of their practical use in the classroom. The remaining two students, B and J, referred to the overall "historical background" of topics in general. Overall the highest number of postings occurred during the Dido problem discussions. The second highest number of postings was for the trisection problem. The high number of postings to these discussions possibly reflects student motivation and engagement with the tasks.

The last question "Which task(s) led to the richest exchange of ideas with your classmates?" resulted in ten of twelve responses referring to the problems and proofs. Student H referred to the problems and the lesson plans and Student D responded "the discussions in response to the readings." Content analysis results showed the problem of Dido led to the highest number of postings and the highest number of postings coded as Exploration, Integration and Resolution when compared to all other assignments. This problem in particular, although not specifically referred to by every student, resulted in a rich exchange of ideas as shown via content analysis.

COI Survey Results

The Community of Inquiry Survey (Garrison et al., 2007) was distributed to the MATH 500 students as part of the post-course survey (see Appendix B). The survey was designed by the researchers to validate the three constructs of the Community of Inquiry framework: 1) teaching presence, 2) social presence, and 3) cognitive presence. Additionally, the researchers hoped the instrument would be used as a post-course tool in online courses for assessing student perceptions of teaching, social, and cognitive presence. Since it is not feasible to perform exhaustive content analysis on discussions from every online course, the survey would present a more "user-friendly" tool for analyzing each presence.

Each element of the COI framework is further broken down into categories. The three categories of teaching presence are design and organization (DO), facilitating discourse (FD), and direct instruction (DI). The three categories of social presence are affective expressions (AE), open communication (OC), and group cohesion (GC). And the three categories of cognitive presence are triggering event, exploration, integration, and resolution. Results of student responses to the COI survey are summarized in Table 16 in terms of average response on a five point Likert-type scale where 1 is strongly disagree, 3 is neutral, and 5 is strongly agree.

By Student

    Students M, G, and K each had overall averages for both the teaching presence

and social presence elements that were less than 4 (where 4 represented agreement).

Students J and K were the only students to have averages lower than 4 for responses to

Table 16

Community of Inquiry Survey Results

Student	Teaching Presence				Social Presence				Cognitive Presence				
	DO	FD	DI	Overall	AE	OC	GC	Overall	TE	EX	IN	RE	Overall
B	4.5	4.3	4	4.3	3.3	5	3.7	4	5	5	4.7	4	4.7
M	3.8	3.2	3.7	3.5	2.3	4	3	3.1	4.7	4	4	3.7	4.1
A	4.8	4.7	4	4.5	4.7	5	5	4.9	5	5	4.7	5	4.9
I	5	3.8	4.7	4.4	3.7	5	3.7	4.1	4.3	4	4	4	4.1
L	4.8	5	5	4.9	4	5	4.7	4.6	5	4.7	5	5	4.9
J	4.8	4.7	4.7	4.7	4	4	4	4	3.7	3.7	4	4.3	3.9
D	5	4.3	5	4.7	4	4	5	4.3	5	4.3	4.3	3.3	4.3
P	4.8	4.8	4.7	4.8	3	4.7	5	4.2	5	4.7	4.3	4	4.5
G	3.8	3.7	3	3.5	3.3	3.7	3	3.3	4.3	4	3.7	4.3	4.1
K	4	3.5	4	3.8	3	3	3	3	3.7	4	3.3	3.7	3.7
N	5	4.8	4.3	4.8	3.7	5	4.3	4.3	4	4.3	4.7	4	4.3
Q	4.3	4	3.3	3.9	4.3	4.7	4	4.3	4.3	4	3.7	4	4
H	4.8	4.7	5	4.8	4.3	5	5	4.8	5	4.7	5	4	4.7
Overall	4.5	4.3	4.3	4.3	3.7	4.5	4.1	4.1	4.5	4.3	4.3	4.1	4.3

the cognitive presence element. Thus it would seem that students were in agreement that

each presence was well represented in the online course.

By COI elements

    The social presence category "affective expression" is the only category that had

an overall average less than 4. Affective expression specifically refers to the emotional

expressions within computer conferencing that students use such as emoticons, humor,

and self-disclosure. In particular the statement from this category that "Online or Web-

based communication is an excellent medium for social interaction" received the lowest

score for the entire survey. As seen in Table 16 several students had a low overall average for this category of social presence.

Summary

In this chapter, results of data analysis have been presented from several perspectives. First, the validation and modification of the protocol itself were discussed. Tasks assigned in MATH 500 were also described in detail, and task types were developed. The results of content analysis were presented as a whole, in terms of individual students, and in terms of tasks and task types. Chapter 5 will offer conclusions and recommendations drawn from this rich source of data.

CHAPTER FIVE

CONCLUSIONS

Introduction

This chapter opens with an overview of the purpose of this study and the methodologies used in the study. Next, the conclusions and implications drawn by the researcher from the results presented in Chapter 4 will be discussed in relation to the relevant literature. Finally, recommendations for further research will be suggested.

Overview of the Study

The implementation of online distance education, specifically asynchronous learning networks, has far outpaced our knowledge of its effectiveness as a learning tool in education. The literature acknowledges the potential of ALNs to promote knowledge construction due to its reflective and interactive properties. However, a number of studies focusing on knowledge construction have found that it is difficult to move inquiry past the exploration phase or the exchange of information (Fahy et al., 2001; Garrison et al., 2001; Kanuka and Anderson, 1998; Littleton & Whitelock, 2005; McLoughlin & Luca, 2000; Meyer, 2003). Researchers have conjectured that this is due to the nature of the tasks assigned (Arnold & Ducate, 2006; Hara et al., 2000; Kanuka & Anderson, 1998; Meyer, 2004).

Very few studies have offered research-based recommendations about online pedagogy in higher education, although expository "how-to" books and guides for

practitioners of online education are now readily available. The need for further research

to extend the educational community's knowledge of online learning transactions that

result in meaningful and worthwhile learning is becoming critical (Kanuka & Garrison,

2004). To address both issues, the purpose of this study was to look for evidence of

higher order learning, or cognitive presence as defined by Garrison et al. (2001), in an

online learning context and to explore whether one component of instruction, the tasks

assigned to students, had an effect on the level of cognitive presence that was achieved in

the discussions.

The context of this study was an asynchronous online graduate course for

practicing mathematics teachers in a Master of Science program. The course contained

both mathematical content and pedagogical applications related to the history of

mathematics. The course instructor, a professor of mathematics education experienced in

its online implementation, designed all tasks for the course.

The online discussion transcripts were the main source of data for the study. Nine

hundred seventy-six messages were analyzed to assess the level of cognitive presence

that was evident in the discussion transcripts using a slightly modified version of

Garrison et al.'s (2001) cognitive presence coding protocol. A message was chosen as

the unit of analysis and each was coded to one of six categories:

(a) Comment, (b) Teacher Presence, (c) Triggering Event, (d) Exploration, (e)

Integration, or (f) Resolution.

Sixteen of the seventeen students enrolled in the course chose to participate in the

study by returning an IRB approved subject consent form and responding to a

questionnaire used to collect demographic and background information. Thirteen of the participants chose to also respond to a post-course survey used to assess student perceptions of online tasks and discussions. The researcher interviewed the instructor at length and used his responses to build an accurate description of his background and of the MMTE program, and also to ascertain his views on various aspects of teaching and learning in the online medium. Together the questionnaire, survey, and interview served as a source of data for triangulation with the data obtained from content analysis of the discussion transcripts.

The transcripts were sorted into nineteen separate assignments identified by the researcher based on instructor postings. Each assignment was categorized as one of three task types, which emerged from the data provided by students and the instructor. Each assignment was coded using the cognitive presence coding protocol. Results of this analysis revealed that the majority of messages were of the sharing and comparing type representative of the Exploration phase of the Practical Inquiry Model. The second highest number of messages was coded to the Integration phase where connections are made between the ideas shared in the Exploration phase and a synthesis of new understandings is created. Coding results were then compared between students, between groups, between assignments, and over time. Transcripts were also read from a qualitative perspective to note trends, social factors, and unique cases.

<u>Conclusions and Implications</u>

The size and complexity of this body of data has led to a complex web of related conclusions, observations, and implications. These will be reported in the order of the research study questions, which are repeated below for reference purposes.

1. Do the discussions generated in MATH 500 demonstrate evidence of higher level thinking in terms of cognitive presence?

2. What is the nature of the tasks that are implemented in MATH 500?

3. Is there evidence of a relationship between the tasks that are implemented in MATH 500 and the levels of cognitive presence observed in the corresponding discussions?

<u>Question #1: Evidence of Cognitive Presence</u>

Eight-hundred twenty messages of the 976 analyzed using the cognitive presence coding protocol were assigned to a phase of the Practical Inquiry Model. These results are shown in Table 2, Chapter 4. Recall that cognitive presence represents the construction of meaning through sustained communication. The Integration and Resolution phases of the Practical Inquiry Model represent the higher levels of critical inquiry (Schrire, 2004, p.485). Overall, the discussions demonstrated evidence of higher order thinking in terms of cognitive presence. Each phase is discussed in more detail below.

<u>Triggering Event:</u> Triggering events accounted for 6 (.61%) of the total number of messages coded in MATH 500. This relatively low number of postings was due to the

structure of the class. Dr. Brook presented the triggering events for each assignment so students were not required to be discussion leaders or to start discussion topics. Also, students typically stayed on task during discussions resulting in a low number of Triggering Events.

Exploration: The majority of the postings (64.65%) in MATH 500 were coded to the Exploration phase of the Practical Inquiry Model. The Exploration phase represents a divergent phase of students sharing and comparing information in response to the Triggering Event. It was noted earlier that a high percentage (49%) of these postings were considered "required postings" in which students were responding to specific assignment instructions. A high proportion of messages coded as Exploration was found in other studies that used Garrison et al.'s (2001) cognitive presence coding protocol directly or in a modified form (Garrison et al., 2001; Meyer, 2003; Pawan et al., 2003). Arnold and Ducate (2006, p.54) stated in their study of social and cognitive presence that the "type of task can explain [the] increased level of explorations (p. 54)." Differences in MATH 500 task types and the levels of cognitive presence they produced will be discussed in another section of this chapter.

Integration: The second highest proportion of messages was coded to the Integration phase of the Practical Inquiry Model. In the Integration phase students make connections between the ideas that are shared in the Exploration phase and create a synthesis of new understandings. The presence of messages in this phase reveals the social construction of knowledge (Schrire, 2004). When considering all six categories of

the coding protocol, 15.88% of all messages were coded as Integration. Omitting the

Comment and Teacher Presence categories and considering only the four phases of the

Practical Inquiry Model increased this percentage to 18.90%. And finally, when required

postings were left out of the Exploration phase 30.16% of the messages were coded as

Integration.

So what can be concluded about cognitive presence? As stated previously,

normative data does not exist in the literature for interpretation of quantitative content

analysis results (Rourke & Anderson, 2004). Thus whether 155 messages coded as

Integration represent a high or low number is subject to interpretation. In the next

paragraphs, studies that used the cognitive presence coding protocol of Garrison et al.

(2001) are discussed in terms of their similarities to the present study. These studies all

sampled graduate students engaged in online coursework in the field of education;

however, they also differ from the present study in significant ways.

A study by Meyer (2003) coded 751 messages from two online graduate level

courses in educational leadership, which included instructor postings that could not be

separated out of the analysis due to the postings being labeled anonymously for coding

purposes. A category of "social" was added to the coding protocol by the researcher; thus

five categories were used for coding. It is not known if students were put into groups or

how experienced the instructors were with online courses. Overall 22.24% of the postings

(167) were coded to the Integration category. Because this study used the cognitive

presence coding protocol of Garrison et al. (2001) and used data from graduate courses, it

was found to be the best comparison to the present study, where 15.88% of all postings were coded as Integration.

Another study by Meyer (2004) which analyzed 278 messages from ten students in doctoral-level classes in educational leadership found 32.4% of the messages were representative of the Integration phase. This study did not look at all students in the class, but rather a subset of ten students over an extended period of time. Discussions were student-led where a student selected the question or topic for discussion related to the class reading of the week.

A study by Arnold and Ducate (2006) analyzed 1,119 speech segments that were considered "cognitive events" from two graduate level courses on foreign language methodology for teachers, and 36.28% were coded to the Integration phase. The courses were a combination of face-to-face and online formats, and instructors provided the triggering questions but did not participate in the discussion postings. Students were assigned to groups of four for the discussions. Groups stayed the same for two discussions and then were changed for the last three discussions. Students in the blended format class used the online portion of the class purely for discussion purposes, thus assignments were not posted to the discussion folders. Should the Arnold and Ducate result of 36.28% be compared to this study's result of 18.90% total Integration postings, or is it more accurately comparable to the result of 30.16% when required postings are left out?

Lastly, a study by Pawan et al. (2003) analyzed 229 speech segments from three graduate-level online language teacher education courses that included both student and

instructor postings. Each course was taught by a different instructor with varied

backgrounds: (a) a doctoral student, (b) an adjunct faculty member, and (c) an assistant

professor. It was the first online course taught by the doctoral student. Each course had

enrollments ranging from 11-13 students and it is not known if smaller groups were

formed for discussion purposes. Overall 11% of the speech segments were coded to the

Integration phase. All but five postings coded as Integration came from the class

instructed by the assistant professor. This class had 80 speech segments coded and 25%

were coded as Integration.

In looking at only these four studies in comparison to the present study, it is clear

why it has been difficult to establish normative data for this body of research. Each study

has similarities to the current project; namely, the data was derived from online

transcripts of graduate courses related to education and the same cognitive presence

coding protocol was used for analysis. Yet many differences also exist that can greatly

influence results such as: (a) characteristics of a blended format course that includes a

face-to-face component versus a purely online course, (b) the unit of analysis chosen for

coding, (c) the size and purpose of discussion groups, (d) the experience of the course

instructor, and (e) the number of messages that were coded.

As stated previously, normative data does not exist in content analysis literature.

Instead, comparisons can only be made to studies that have similarities that are deemed

appropriate by the researcher. By providing thorough reports of the results of content

analysis that contain inter-rater agreement, training procedures for coders, and sample

descriptions of coded transcripts, results can possibly be replicated. Unfortunately, few

researchers use the coding protocols that already exist (Rourke & Anderson, 2004). When existing coding protocols are in fact used, they "contribute to the accumulating validity of an existing procedure, are able to compare their results with a growing catalog of normative data, and leapfrog over the instrument construction process" (Rourke & Anderson, 2004).

Resolution: As stated previously, Integration and Resolution are the phases of the PIM that represent higher order learning. Resolution postings accounted for only 2.87% of the total messages coded to the six categories of the modified cognitive presence coding protocol. This percentage increased to 5.45% when the Comment and Teacher Presence categories were left out as well as any required postings. The low occurrence of Resolution postings echoes the findings of previous studies that employed the cognitive presence coding protocol (Arnold & Ducate, 2006; Garrison et al., 2001; Meyer, 2003; Pawan et al., 2003). Two types of resolution, "forced" and "natural," were identified in this study. As discussed in Chapter 4, a forced resolution was the result of a student meeting a specific task requirement, while natural resolution postings arose out of the discussion. Only nine postings were naturally occurring and 19 were forced.

In three of the studies described above, resolution postings accounted for between 0% and 7% of the postings, comparable to this study's results. However, Meyer (2004) coded 19.8% of the discussion postings as Resolution. The researcher of the current study noticed that in the 2004 study by Meyer, the category Resolution was labeled "Solution," a change from her work in 2003. Meyer (2004, p. 110) also specifically stated that "19.8% of the postings were coded as 'solutions' " (p. 110). In the present study,

solutions to problems were coded to the Integration phase using the indicator "Creating solutions" where students "Explicitly characterize the message as a solution." This difference in perspective could account for the unusually high incidence of postings to the Resolution phase in Meyer's study when compared to the other three studies described earlier and the present study.

The lack of Resolution postings identified in this study may be partially explained by the nature of the Triggering Events. This implication will be addressed later when task types are analyzed in terms of the cognitive presence they produced. It may also be that students are more apt to post multiple messages in the Exploration phase where they are sharing information with one another and in the Integration phase where they are connecting ideas and building on information shared in the Exploration phase, whereas it is less likely that an individual student will achieve Resolution (e.g., "vicariously apply a solution to the real world") more than once per task. Also, the design of this course did not encourage students to question or challenge one another's viewpoint, resulting in only rare occurrences of the "Defending solutions" indicator of Resolution.

Question #2: Nature of Tasks

The assignments given by the instructor in MATH 500 were analyzed individually by the researcher for attributes such as nature of instructions, assignment timelines, and specific requirements and products. The discussions that resulted from the assignments were also analyzed via content analysis to assess the level of cognitive presence that existed. Finally, all discussions were read from a qualitative perspective to identify student exchanges that demonstrated unique traits and behaviors. Each individual

assignment was described in detail in Chapter 4 and requires no further interpretation.

Conclusions that arise from content analysis and from qualitative interpretation of the

transcripts are presented in the following sections.

Question #3: Cognitive Presence by Task Type

Three task types were identified by the researcher from student survey and

instructor interview data: Mathematical Problems, Readings, and Realistic Learning.

Results from content analysis (see Tables 12, 13, and 14 in Chapter 4) revealed that

cognitive presence (Integration or Resolution) existed somewhere within each task type,

but was not consistently represented across all assignments within each task type. For

example, for tasks categorized as Mathematical Problems the number of postings coded

as Integration ranged from 1 to 26. Due to the variance in number of Integration postings

per assignment within each task type, valid conclusions could not be made about the

relationships between cognitive presence and task type. In an effort to make finer

distinctions that might lead to reasonable conclusions about the data, the task types were

further sub-grouped according to similarities the assignments shared as shown in Tables

12, 13, and 14.

Whether Integration postings are considered in terms of number of postings or

percentage of postings is of considerable importance in terms of interpretation. It was

noted above that the number of Integration postings in each Mathematical Problems task

ranged from 1 to 26. Ignoring all required postings, the percentage of Integration

postings for each Mathematical Problems task ranged from 19.28% to 42.11%.

Assignment 6 is at the low end of this percentage range, yet it had the third highest

number (16) of Integration postings for this task type. The researcher chose to interpret

the findings in terms of number of postings rather than overall percentages.

Readings: Of the four sub-categories defined within the Reading task type, the

three ERMO reading summaries had the highest number of postings coded as Integration.

ERMOs typically include a component where students are asked to read the postings of

other students in their group with a critical eye toward improving their own summary.

The first ERMO was the only assignment where the instructor explicitly pointed out this

requirement, but students typically did this in the other ERMOs as well. Peer critiquing

tasks have been found to promote critical thinking (Abrams, 2005), thus this component

of the ERMO summaries is likely a contributing factor to the high number of postings

coded as Integration.

The ERMO tasks of Assignments 1 and 8 had proportionally more integration

postings (and overall postings) than the ERMO in Assignment 4. This could be due to the

pedagogical applications included in the instructions for Assignments 1 and 8. Students

were not asked to connect the content of the readings to their classroom practice in

Assignment 4, which may have left them less personally engaged. Teachers enjoy

reflecting on their teaching and exchanging pedagogical content knowledge (Yang & Liu,

2004). Yet two other assignments (10 and 12) of the Reading task type also asked the

students to make personal connections to their teaching practice, but they did not result in

a high number of Integration postings. These assignments were not ERMOs—they did

not ask students to reflect on and summarize the readings before making the classroom

connections. The assignments that combined a critical reading of literature with an

exercise in pedagogical relevance resulted in higher levels of thinking than the other assignments.

Mathematical Problems: Of the four sub-categories defined within the Mathematical Problems task type, Assignment 2 (the Dido problem) and Assignment 6 (the trisection problem) were found to have the strongest evidence of integration. These assignments also had the highest number of postings coded as Resolution. This result is not surprising considering that the assignment requirements specifically asked the students to apply a part of the problem to their classrooms. Arnold & Ducate (2006) similarly found that explicit questions about teacher practice resulted in a high number of Resolution postings. In a sense, the need for resolution was contrived by the instructor.

Both of these assignments were open-ended and required students to make decisions on how to approach the problems. A specific answer was not expected in either discussion. These assignments had the highest number of overall postings both for this task type and for all of the tasks. This supports the finding of Hiebert & Wearne (1993) that problem-solving tasks that invite alternative solution strategies are naturally associated with discourse demonstrating more frequent and more substantial student responses.

The problem of Dido in particular was cited by the students as a challenging and difficult problem, and the instructor also referred to the problem as difficult in his assignment instructions. In his interviews, Dr. Brook expressed his desire to assign problems that are both challenging and unique:

> Ah, but of course the problems I like to pose are problems that are not the classical ones they've seen already, to make them really think about the math that they teach, and reflect on that math they teach, and partly by challenging them in their own understanding of that math.

It is believed that when tasks are complex and require increased problem solving and creativity, the social support and cognitive benefits are likely to be greater (McLoughlin & Luca, 2000, p.3). By applying problem-solving skills to unique problems, higher order thinking skills are honed (Wenglinsky, 2002).

The implication here is that the combination of a cognitively demanding mathematical problem with a classroom application component results in higher level thinking. Kanuka & Garrison (2004) stated that when students are given opportunities to discuss what they have learned and apply it, higher levels of learning will occur. However, the nature of the mathematical talk of teachers when discussing content versus pedagogy has been found to be quite distinctive. In a 2006 study, Crespo found that teachers functioned as a community and were interactive and collaborative when exploring content-related mathematics, but functioned in a reporting nature when discussing the pedagogical aspects of their classrooms. Perhaps it is the combined power of both components that promotes cognitive presence.

The Mathematical Problem tasks in Assignments 7 and 17 were explored using an applet on the Internet. Students explored the ideas of commensurability in Assignment 11 and explored non-Euclidean Geometry in Assignment 17. This sub-grouping had the second highest number of Integration postings among all Mathematical Problems. The discussion postings in response to Assignment 7 did not address the instructor-prompted questions; instead, the students focused on how to implement the applet into their

classrooms. Thus students transformed the discussion into something they wanted to talk about rather than what the instructor expected them to explore. There was no intervention of teaching presence to re-focus the discussion. This could have been intentional, as the instructor may have felt the students were interacting in a productive manner.

In the discussion associated with Assignment 17, eight of the ten Integration postings that resulted were due to the instructor intervening with a prompt within the discussion. The instructor asked the students to approach the problem in a different way and pushed them further in their exploration of the topic. Hiebert and Wearne noted that "Spending more time on a problem and using alternative representations to set up and solve a problem would seem to encourage more reflection and would allow for constructing additional mathematical relationships" (1993, p.421). Prior to this intervention, the majority of the postings were required postings.

In these two assignments, it is apparent that the type of task was not the contributing factor in whether students posted messages that reached Integration or above. Instead, student disregard for the instructor's triggering message in favor of pursuing a topic of greater interest led to the discussion in Assignment 7. And the instructor's teaching presence, not the original task, led to a discussion in Assignment 17 that resulted in higher levels of thinking. These examples suggest that the instructor has both influence and responsibility to focus students and push them to higher-level thinking. Teaching presence is essential to the educational experience and contributes to the adoption of a deep approach to learning (Garrison & Cleveland-Innes, 2005).

Realistic Learning: Three sub-categories were defined within the Realistic

Learning task type, with Assignment 13 comprising a tentative fourth sub-category.

Because the mathematical problem in Assignment 13 was solved by both the class

members and their own students, it was also analyzed as a Mathematical Problems task

type. Assignment 16, which involved the construction of a lesson plan, had the highest

number of Integration postings. Assignment 18, another lesson plan with nearly identical

instructions, ironically had zero Integration postings. Structural differences in carrying

out the assignment may explain this difference. In Assignment 18 there were no

discussion groups; instead, the entire class contributed to one large group. This could

have confused the class since the instructions stated, "When you are finished with your

lesson, each member of your group is going to have to answer some questions about your

lesson plan." This was followed with "I am creating a common folder for the entire class

to use in posting their lessons." And in addition to posting instructions for Assignment

16, the instructor posted a message to the related discussion thread reiterating what

students needed to do:

> You should feel free to ask each other questions about [their] lessons since some
> times the plans might be difficult to visualize. You should also feel free to
> discuss variations that your group comes up with for your lesson or others lessons.
> Each of you has a unique and valuable perspective to share. Let's share it and
> learn from each other.

Assignment 18 was an example of a case where inconsistencies in Dr. Brooke's

instructions may have contributed to a lack of cognitive presence. On the other hand, his

clarification of instructions in Assignment 16 may have supported high-level discourse.

<u>Individual Observations</u>

In comparing the seven students who were found to have a higher number of Integration postings with the nine students who demonstrated lower instances of integration, patterns were found among levels of teaching and degrees earned. High school mathematics teachers who taught Algebra and/or Geometry as their highest level class in the two years prior fell into the higher group. Surprisingly, the high school teachers who taught Pre-calculus and/or Calculus fell into the low-performing group. A possible explanation for this occurrence is that the mathematical content explored in MATH 500 demands significantly more content knowledge of material from Algebra and/or Geometry than from Pre-calculus and/or Calculus. Dr. Brook confirmed that Algebra and Geometry content was used more in the class than Pre-calculus and Calculus. Also Student L stated in her post-course survey: "The area of a regular polygon was a very challenging task, and I found my way into the task from a task I give my students in high school Geometry." The high-performing students may have been able to apply the content they were currently teaching to both mathematical content problems and pedagogical explorations.

Another interesting result was that all four middle school mathematics teachers fell into the low-performing group. The mathematical training of these teachers, combined with the level of mathematics they encountered on a daily basis, may have restricted their success with the challenging content of the mathematical problems. Thus, the ability of teachers to engage in knowledge construction with their peers might be directly related to the baseline knowledge that the teachers possess.

Research suggests that teacher content knowledge has a significant effect on student learning in K-12 mathematics classroom (Ball, 2003). The same appears to be true of the presence of higher-order learning among teachers who are also learners themselves. Five of the seven students with a Bachelor of Science Degree in Mathematics were identified as high performers. Of the remaining two mathematics majors, one was very new to MMTE, distance learning, and how to participate in online discussions, which may have led to limited cognitive presence. The second person did not have any identifiable characteristics that would explain placement into the lower group.

In general, students with a B.S. in Mathematics demonstrated higher levels of Integration when addressing the history-based content explored in MATH 500, possibly because of the stronger background they had in mathematics content. Years of mathematics teaching experience, gender, and age were mixed in both groups, thus the researcher did not attribute differences in the number of Integration postings to these factors. Prior experience in the MMTE program also did not appear to be a contributing factor.

Student Characteristics and "Characters"

Along with analyzing the results of content analysis in terms of counts and percentages, the researcher examined the overall behavior of individual students and groups. Some trends held true for the entire class; for instance, all students but one posted at least one message at the Integration phase, and each student posted most frequently to the Exploration phase of the Practical Inquiry Model. Such similarities are easy to identify in the descriptive data tables. However, further qualitative analysis

provides a much richer description in terms of the differences between students, their

posting habits, and their approach to online collaboration.

Low Posting, High Integration Students I and G: Student I posted only 38

messages that were coded to the four phases of the PIM, surpassing only five students in

total PIM postings and finishing well below the class average of 50 messages (median

52.5). However, 11 of Student G's messages were coded as Integration and one as

Resolution. In all other cases but one (Student G), students with a high number of

Integration postings also had a high number of postings overall. This result implies that it

is not necessary for students to post a high quantity of messages in order to achieve high

quality in terms of higher order thinking.

In responding to the post-course survey, these two students stated that their

participation was motivated more by the class requirement than by desire to participate.

Posting to the discussions and working collaboratively did not come naturally for these

two students, as evidenced by their "neutral" responses to each of the following

statements regarding social presence: (a) Online or web-based communication is an

excellent medium for social interaction, and (b) Online discussions help me to develop a

sense of collaboration.

It is possible that, despite their lack of interest in participating in discussions, each

of these students may have desired to meet course objectives and earn a good grade, so

they participated to meet expectations. Students such as these are often referred to as

achievement learners who look to the external reward given for demonstrating learning

(Garrison & Cleveland-Innes, 2005). An example of this behavior is an assignment where

students were supposed to post their thoughts on a chapter they read from a text. Student I was the first person in his group to realize that this was not happening as expected. In a posting he wrote, "Oh, I just noticed we are supposed to reflect on the chapter," then went ahead and did so. Student G was also the only person in his group to reflect on the chapter.

Yet apparently these same students did not find the discussions compelling enough to warrant excessive posting. In particular, Student I seemed to prefer reflecting as an individual rather than collaboratively with his group. He often posted his work without reference to the group; instead it seemed that he was in a group of one. He fit the Integration indicator of "convergence within a single message" rather than "convergence among group members." In other words, he managed to create cognitive presence without contributing to social presence. Garrison et al. (2000) note that, "Critical inquiry and the quality of discourse is facilitated and optimized when students see themselves as part of a group rather than as individuals" (p. 101) so finding strategies to enhance the student's sense of group cohesion would likely benefit the discussion group.

Student G, on the other hand, did work collaboratively within his group, but his postings were typically a requirement of the assignment or, occasionally, when his interest was piqued. He was a self-proclaimed introvert that preferred to work alone, but when interest was sparked, he did build upon ideas brought about in the group as shown in the results section titled "Assignment 8" in Chapter 4. Student G needed topics that were personally relevant in order to become involved in the discussions. This finding supports the work of Van Zoest and Enyart (1998), who pointed to the need for a task to

engage students' interest, pique their curiosity, and relate to them in order to provide a stimulus for discourse. Student G seemed to respond positively to student-initiated triggers. Perhaps his participation would increase if more tasks provided opportunities for students to create Triggering Events.

<u>Low Posting, Low Integration Students K, O, and C:</u> Students K and O were similar in many ways: age, gender, degrees earned, level of mathematics taught, and online course experience. They were also among the lowest performers in the course discussions. An "excuse" might be made for Student K's lack of both quantity and quality of participation, as he lacked experience both in teaching mathematics and in taking online MMTE courses. Yet two other students in the course lacked this same experience and did not perform as Student K did.

What was strikingly different about Student K was his response to the post-course survey; he had the lowest overall average response of any student. In particular, Student K responded neutrally to the teaching presence category "Facilitation" which referred to the instructor's role in guiding students in understanding, engaging students in discussions, and keeping discussions on task. Teaching presence has been cited in numerous studies as an important aspect in moving students from Exploration to higher levels of thinking (Bullen, 1998; Garrison et al., 2000; Garrison et. al, 2005; Kanuka & Anderson, 1998; McLoughlin & Luca, 2000). Student K also responded neutrally to every single statement (9 total statements) for the social presence element. Due to the overwhelming number of neutral responses by Student K the researcher wondered if these responses were truly neutral or actually areas of disagreement. Student G also had a

high number of neutrals for responses to the social presence element and, as stated previously, was not fond of online communication overall. "Socio-emotional interaction and support are important and sometimes essential in realizing meaningful and worthwhile educational outcomes" such as cognitive presence (Garrison et al., 2000, p. 95). Student K's lack of social presence in discussions may have led to his lack of cognitive presence.

Student O was specifically mentioned by the instructor as a person who brought different perspectives to online course discussions and often stimulated an engaging conversation. However, this did not happen in MATH 500. Student O also did not return the post-course survey and did not communicate as to why he chose not to return the survey. There is no known explanation for his poor participation.

Student C completed the course with the least number of Integration postings. Like Students O and K, he rarely posted and often posted messages late. On some occasions, Student C did not even post required messages. Overall, this student had only four non-required postings coded to the Practical Inquiry Model phases, the lowest contribution of any student. This student, not surprisingly, chose not to return the post-course survey. Student C was experienced in teaching mathematics and in taking online MMTE courses; the reasons for his poor performance in MATH 500 are a matter of speculation.

High Posting, High Integration Students D and L: Student D had the highest number of messages coded to the Integration phase of the PIM. This student was unique in several ways including a more mature age, teaching experience at the post-secondary

level, a focus on developmental mathematics, and significant years of mathematics

teaching experience, although she held only a minor in mathematics.

Even more unique was the way in which this student interacted in the course

discussions. Unlike the typical student in the course, Student D did not limit herself to her

own group, but also participated in other group discussions. Frequently the student

would jump into other groups to engage in conversation, correct misconceptions, answer

questions that were posed, and ask his own questions. Student D responded to the

statement "Online or web-based communication is an excellent medium for social

interaction" on the post-course survey with a 3, which represented a neutral response. It

is possible that this student did not find the type of interaction she needed in her own

group, which led her to seek more rewarding social interaction by visiting other groups.

Student D was not only engaging as a peer, but also as a leader in terms of

teaching presence, which was a benefit to her as well as other students. Giving

explanations and actively teaching someone else requires the person to clarify the

material in a new way, thus helping the person to understand the material better (Webb,

1991). The role of instructor could be deeply embedded in this student to the point where

taking the "teacher" out of the "student' is nearly impossible, thus leading Student D to

naturally take on the role of instructor. A critical community of inquiry with appropriate

cognitive and social presence is dependent upon the types of teaching presence displayed

by Student D (Garrison & Cleveland-Innes, 2005).

Student L shared similar traits with Student D; she was also a more mature

student and had only a minor in mathematics. Like Student D, she had a high number of

Integration postings (third highest in the course) and a high number of overall postings in the course (third highest in the course). Student L also visited other groups frequently to answer questions that were posed, creating teaching presence among her peers. When assigned to the same group for Unit One, Students L and D were highly interactive with one another and produced a high number of Integration postings as described in Chapter 4.

Unique Findings

The following observations do not directly address the research questions, but they represent unique findings that arose from the data analysis. Each case is described in terms of one or more students; however, more students than those named may have contributed to the case.

Alone in a Crowd Student Q: Student Q, unlike students I and G, had a high number of postings but did not have a high number of Integration postings. This was more likely due to his second group assignment than to his lack of effort. One group member dropped the course midway through the semester, and two others (K and O) were chronically late with postings and overall had a low number of postings. Student I was in Student Q's group for most of the semester, but preferred to work individually rather than collaboratively. Student Q repeatedly posted comments and questions, but was not able to get a response from others in the group. It is believed that students who pose questions but receive no response will experience negative effects in learning and

motivation (Webb, 1991). This appeared to be the case with Student Q, who eventually gave up trying to pose questions and work collaboratively.

Making Excuses Students K and M: Often during the MATH 500 course students would post a message stating that they were going to complete a task in the near future. It was not uncommon to see late or partial postings accompanied by excuses and promises that the student would soon post valuable material, but as often as not that material was not forthcoming. For instance, during the Problem of Dido discussion Student K stated that since he had nothing to offer to move the group forward, he would piece together what had been done so far and write up a summary. Student K did not post again to the discussion thread. Student M provided another example of this lack of follow-up when he posted a message stating his acknowledgement of being a "COMPLETE slacker on Unit 4" but then never posted again to the discussion. Student M also offered an excuse for his non-participation as many other students did throughout the course. This trend seems to relate to social presence; the students feel a sense of responsibility to their groups, even when they aren't contributing as they should. Teaching presence on the part of the instructor may have been needed to stress to the "repeat offenders" the importance of timely communication within their groups.

Disregarding Instructions Multiple Students: Several of the assignments in MATH 500 resulted in students either failing to post required parts of an assignment or not responding to the specific triggering questions posed by the instructor. For example, in Assignment 5 students were asked to propose an answer to the whole class for the

question: "Should teachers use stories from the history of mathematics in their teaching of mathematics?" None of the groups proposed an answer to the whole class; students posted their position on the question and left it at that. It seemed the groups viewed the task as non-collaborative in nature and not in need of a final negotiated group product.

In Assignment 7, students were asked to share their understanding of two quantities being commensurable or incommensurable based on an applet activity. They were then to discuss what this might imply about the existence of irrational numbers. In one group the first posting addressed these questions, but the discussion took a new direction when a fellow student focused the discussion on the applet. The rest of the discussion related to the applet's use in classroom practice. In this situation, students felt drawn to discussing the practical relevance of the applet rather than the theoretical ideas it was intended to enforce.

In both assignments, teaching presence on the part of the instructor or a student would have likely changed this behavior. The instructor could have re-focused the discussions by reminding the students that the requirements were not being met. A student could have done the same thing; whether or not this would have had the same effect is material for another study.

A Deeper Look at Dido

When the nineteen assignments were analyzed as stand-alone tasks, Assignment 2, the problem of Dido with classroom applications, stood out from every other task in terms of total number of postings, cognitive presence, student perceptions, and overall collaborative interaction within the discussions. The Dido problem resulted in a total of

146 postings to the online discussion. The next highest number of postings in the course was 105 for Assignment 6. Of these 146 postings, zero were coded as required postings since the students separately emailed their individual final proofs to the instructor. Content analysis revealed that the highest number of postings for every phase of the Practical Inquiry Model was attributed to the problem of Dido. Also, the highest number of messages coded as Teacher Presence occurred during these discussions.

Students repeatedly referred to the Problem of Dido in the post-course surveys as noted in the following excerpts: "It made me think for days and talk to classmates," "Dido's problem seemed to create the most discussion because of the complexity of the proof," "The area of a regular polygon was a very challenging task." Several students also recognized the need for discussion in approaching challenging problems that are less familiar to them. Student P stated, "You NEED to talk to other people to do problems like Dido."

Other contributing factors may have been the timing of the assignment and the time provided for discussion. The Dido problem was given two weeks for discussion, which was the longest time period given to one task. Giving students a longer period of time to reflect and interact may have contributed to the high number of postings for each category of the cognitive presence coding protocol. Also, the problem of Dido was the second task assigned in the course. At this point in MATH 500 this assignment was the only task the students were working on. As the course progressed, tasks began to overlap one another making it harder for students to focus on only one task. The logistics of

assigning the task may have contributed to its effectiveness; however, the quality of the

task itself clearly played a significant role as well.

In the preceding sections, the researcher has attempted to portray the nature and

quality of discourse in an online graduate course populated by practicing mathematics

teachers. Conclusions and implications have been presented using multiple perspectives,

including the analysis of overall class performance, individual student performance,

results from individual tasks and results from grouped tasks. The chapter concludes with

a final summary of findings in terms of the research questions, followed by

recommendations for continued research.

Summary of Findings

This study analyzed discussion transcripts and other sources of data for evidence

of higher order learning in terms of cognitive presence in MATH 500, an online course

offered to teachers in Fall 2007. Although normative data does not exist for evaluating

the quantitative results, they were compared with other research studies that used the

cognitive presence coding protocol of Garrison et al. (2001) to analyze online discussions

of graduate students involved in education. Content analysis results were comparable to

previous studies. The researcher concluded that the MATH 500 course discussions did

provide evidence of higher order learning in terms of cognitive presence.

Three task types were created based on instructor descriptions of commonly

implemented online tasks and student perceptions of tasks encountered in MATH 500.

Within each task type there were assignments that produced evidence of both high and

low levels of cognitive presence. Task type, as defined in this study, was not directly related to the levels of cognitive presence achieved in the course. This finding does not negate the possibility of such a relationship, but in this study the effects of task type could not be isolated from other features of the course structure and assignments.

Sub-groupings of tasks within each task type that had strong similarities were analyzed for a more in depth look at the tasks in terms of cognitive presence. The problem of Dido and trisection problem were complex and challenging and demonstrated the highest levels of cognitive presence within the Mathematical Problem type. The ERMOS that also contained classroom applications demonstrated the highest level of cognitive presence within the Reading task type. And lastly, the lesson plan that contained specific student instructions to critique one another's lessons in small groups resulted in the highest level of cognitive presence within the Realistic Learning task type.

Recommendations for Further Research

This study involved one online mathematics class taught by one experienced online instructor in a Master of Science program for practicing mathematics teachers. Arbaugh (2007) noted that the level of study and characteristics of a degree program may possibly influence the occurrence of cognitive presence in online learning, so research that will be compared to this study should be limited to similar programs at a similar level. Replication of this study with several classes in the MMTE program would strengthen the findings and provide a research base not only for continued study of this program, but for online mathematics content and pedagogy courses in other contexts. The

results regarding individual courses could conceivably be generalized to a variety of online professional development courses and workshops for mathematics teachers.

The present study allowed the instructor complete freedom in designing and implementing the tasks that made up the course. A study in which the instructor assigns carefully structured tasks from well-defined task types, possibly repeating them over time, might make potential relationships between task type and cognitive presence more transparent.

A future study could analyze and categorize instructions and tasks from archived online MMTE courses across instructors and courses, resulting in a representative sample of all tasks currently used in the MMTE program. Categorization of these tasks into a typology based on similar traits would provide a basis for further studies into mathematical task types in the MMTE program. From there, numerous studies could evolve to gain a deeper knowledge of how tasks influence the existence of cognitive presence in the online mathematics classroom. Such studies could compare cognitive presence among tasks within task type, among tasks across task types, between content-based and pedagogy-based tasks, and among tasks at varying levels of cognitive demand (difficulty level).

The course used for this study was based on the history of mathematics. Most students stated that they had not been previously exposed to the content of the course and that it was very new to them; in addition, most had not used historical topics in mathematics in classroom practice at all. This is quite different from a mathematics pedagogy course based on instructional strategies or assessment practices. In this case,

the course material relates more directly to the everyday lives of the course participants and their classroom practices. A comparison study between two such courses (content-based and pedagogy-based) could reveal differences in the levels of engagement and cognitive presence among the course participants. A further extension could compare tasks that are "static," whether mathematical or pedagogical, with tasks that call for real-time application to the classroom.

It would be useful to explore whether increased student awareness of the expectations and affordances of asynchronous online discussions leads to increases in cognitive presence. Are students aware that ALNs have the potential to enhance co-construction of knowledge? How do students define critical thinking or cognitive presence? Do they recognize and value the difference between high and low phases of cognitive presence as defined by the Practical Inquiry Model? Do students know how to interact in an asynchronous online environment in order to proactively enhance their learning? Increasing students' meta-cognitive awareness of their behavior in an asynchronous online environment and the possibilities for increased levels of higher order thinking could in essence teach students how to think and communicate in an online asynchronous discussion so that it benefits their learning. An experiment could be designed wherein students are introduced to the cognitive presence coding protocol and the meaning of its four phases. They could then have opportunities to perform content analysis on anonymous discussion transcripts, and perhaps their own transcripts. Levels of cognitive presence could be compared between students who received such meta-

cognitive enhancement and students who were not given meta-cognitive tools for learning.

Finally, within the online discussions of this study, both collaborative construction of knowledge and individual construction of knowledge occurred. The present study suggests that the two different types of knowledge construction are due in part to individual student characteristics (personality) and/or group dynamics (non-participation of students in groups). A study could be designed to determine whether these two factors (one internal and innate, one external and controllable) can be overcome by task design. For example, can the "individualists" be persuaded to participate collaboratively through role playing, project-based activities, forced collaborative structures, or other means? Are such efforts to promote collaboration important, or should individuals who prefer working alone be left to do so? Analysis of group activity coupled with interviews with students could possibly shed light on these questions.

Conclusion

This study arose from a theoretical framework for online knowledge construction that combines socioculturalism with the more recently developed Community of Inquiry model. Socioculturalism focuses on the importance of communication and social interaction within a culture to support knowledge construction. The Community of Inquiry model transfers the principles of socioculturalism to the online learning environment. Based on indicators of cognitive presence, the researcher found that learners in MATH 500 constructed knowledge collaboratively and individually in the

online course, and that the completion and discussion of mathematical tasks contributed

to knowledge construction in various ways. More research is needed to develop

normative data and to further validate the coding protocols used for content analysis in

this context and others.

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APPENDICES

APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

<u>Distance Learner Demographic Questionnaire</u>

Thank you for completing the following questionnaire. Your participation will support my research about online learning among mathematics teachers. Your responses will help me better describe the population of learners in my study. Please list your response to each of the nine multiple choice questions next to "Answer:"

Once the questionnaire is completed, please send it back to me by either:
1) emailing it as an MS Word attachment to XXX
2) copying and pasting the entire document into your email
3) if you prefer you may mail a hard copy to: XXX

If you have problems sending it back please contact me via the above email or call me at XXX for assistance. I will send you confirmation via email when I receive your questionnaire. As a reminder all responses are confidential. **Please return by Nov. 19th.**

Name: (please type your name here)
Email: (please type your email so that I can confirm receipt of the questionnaire)

1) What is your age?
   a) Under 25
   b) 25-34
   c) 35-49
   d) Over 50

Answer:

2) What is your gender?
   a) female
   b) male

Answer:

3) What is your geographical location? Please pick the most specific that applies.
   a) Within 30 miles of Bozeman
   b) Another location in Montana
   c) Western United States
   d) Other US region: (please describe)_____

   e) Foreign country: (please describe)_____

Answer:

4) What degrees have you previously earned?
   a) Elementary Education
   b) Secondary Education (mathematics)
   c) B.S. in Mathematics
   d) Other degrees: (please describe)_____

Answer:

5) How many years of professional mathematics teaching experience do you have?
   a) 0-4
   b) 5-9
   c) 10-14
   d) 15 or more

Answer:

6) What level of mathematics do you currently teach?
   a) middle school
   b) high school
   c) community college
   d) university
   e) other: (please describe)_____

Answer:

7) What is the highest level of mathematics you have taught in the last two years?
   a) middle school
   b) pre-algebra/basic math
   c) algebra sequence/geometry
   d) pre-calculus/advanced math
   e) calculus/AP/IB
   f) other: (please describe)_____

Answer:

8) How many **previous online** classes have you taken using the WebCT platform (exclude current courses this semester)?
   a) 0
   b) 1-2
   c) 3-4
   d) Over 4

Answer:

9) What is your current status in MSU's Master of Science in Mathematics – Mathematics Education (MSMME) program?
   a) I am a non-degree student
   b) I have taken 0-10 MSMME credits
   c) I have more than 10 MSMME credits

Answer:

10) How many **previous online** classes have you taken through the MSMME program (exclude current courses this semester)?
   a) 0
   b) 1
   c) 2
   d) 3 or more

Answer:

APPENDIX B

POST-COURSE SURVEY

Thank you for completing the following survey regarding Math 500 Fall Semester. As stated in the consent form, responses to the survey will be kept confidential with no information given to the instructor. The first half of the survey contains open-ended response questions. The second half of the survey contains likert-type questions. Please answer all questions the best you can. If you choose to complete only parts of the survey, that is fine, still return the entire survey.

The survey is pasted below AND attached as a Word document. Please return your responses to me by one of the following methods:

- Downloading and completing the attached Word document and then emailing it as an attachment to XXX.
- Copying the survey as it appears below, pasting it into your regular email, and responding to each question within the email and sending it to XXX.
- Downloading and completing the attached Word document and mailing the hard copy to: Diana Colt XXX
- Downloading and completing the attached Word document and faxing it to: XXX

I can also mail you a hard copy if you would like. Just email me your address.

I will email you when I receive your survey, confirming it was received. I will continue to contact you until the survey is returned, so if you have chosen to no longer participate, please let me know and I will not contact you any further. I can't express my thanks enough for your help in completing the previous questionnaire and this survey. Thank you Thank you Thank you!

If you are willing to be contacted for an interview by phone, mail, and/or email, please provide your contact information below. If you do not fill in any of the information, I will assume you are not willing to be contacted and I thank you for participating in this study.

Email:

Telephone number:

Address:

Sincerely – Diana Colt

MATH 500 End-of-Course Survey

1. Suppose a friend interested in taking MATH 500 next year asked "what did you do in the class?" forcing you to think back to the different tasks and assignments you completed. Create a generalized list for this person that categorizes these tasks according to their similar features and expectations. Avoid naming specific assignments (e.g., the Dido problem) and instead describe the <u>types</u> of tasks you encountered. For example, you might identify a category of tasks called "reading summaries."

The following questions will ask you to reflect upon and analyze the tasks, and your actions in completing the different assigned tasks, in MATH 500. You may wish to describe a generic type of task using the categories you created above (such as reading summaries) or reference specific tasks (such as the Luke Hodgkins article summary)—either or both is fine.

2. Which task(s) caused you to brainstorm and exchange information with your peers in order to make sense of the material addressed by the task at hand? Briefly explain how/why.

3. Which task(s) caused you to make connections between ideas presented and synthesize the information you encountered in order to create new understandings of the course material/topics? Briefly explain how/why.

4. Which task(s) allowed you to develop and justify solutions, hypotheses, or beliefs? Briefly explain how/why.

5. Which task(s) allowed you to discover new ideas that you could apply to your teaching practice? Briefly describe how/why.

6. Which task(s) did you find most personally engaging and motivating, and why?

7. Which task(s) led to the richest exchange of ideas with your classmates?

Please respond to each statement, in terms of MATH 500, according to the scale below. Place your rating at the end of each statement.

5 point Likert-type scale

1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree

1. The instructor clearly communicated important course topics.

2. The instructor clearly communicated important course goals.

3. The instructor provided clear instructions on how to participate in course learning activities.

4. The instructor clearly communicated important due dates/time frames for learning activities.

5. The instructor was helpful in identifying areas of agreement and disagreement on course topics that helped me to learn.

6. The instructor was helpful in guiding the class towards understanding course topics in a way that helped me clarify my thinking.

7. The instructor helped to keep course participants engaged and participating in productive dialogue.

8. The instructor helped keep the course participants on task in a way that helped me to learn.

9. The instructor encouraged course participants to explore new concepts in this course.

10. Instructor actions reinforced the development of a sense of community among course participants.

11. The instructor helped to focus discussion on relevant issues in a way that helped me to learn.

12. The instructor provided feedback that helped me understand my strengths and weaknesses.

13. The instructor provided feedback in a timely fashion.

14. Getting to know other course participants gave me a sense of belonging in the course.

15. I was able to form distinct impressions of some course participants.

16. Online or web-based communication is an excellent medium for social interaction.

17. I felt comfortable conversing through the online medium.

1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree

18. I felt comfortable participating in the course discussions.

19. I felt comfortable interacting with other course participants.

20. I felt comfortable disagreeing with other course participants while still maintaining a sense of trust.

21. I felt that my point of view was acknowledged by other course participants.

22. Online discussions help me to develop a sense of collaboration.

23. Problems posed increased my interest in course issues.

24. Course activities piqued my curiosity.

25. I felt motivated to explore content related questions.

26. I utilized a variety of information sources to explore problems posed in this course.

27. Brainstorming and finding relevant information helped me resolve content related questions.

28. Online discussions were valuable in helping me appreciate different perspectives.

29. Combining new information helped me answer questions raised in course activities.

30. Learning activities helped me construct explanations/solutions.

31. Reflection on course content and discussions helped me understand fundamental concepts in this class.

32. I can describe ways to test and apply the knowledge created in this course.

33. I have developed solutions to course problems that can be applied in practice.

34. I can apply the knowledge created in this course to my work or other non-class related activities.

YOU ARE DONE! Thank you for your time!

APPENDIX C

INSTRUCTOR INTERVIEW

Interviewee:

Date:

Time:

<u>Opening remarks to the participant:</u>

- I will be taking notes during the interview
- With your permission, the interview will be tape recorded as well
- Everything said is confidential – no personal identification of you or your school will be made
- Transcripts of the interview will be made available if you request them
- If any question is not clear feel free to stop and ask me to repeat, rephrase, or elaborate

<div align="center">INTERVIEW</div>

1) What is your background?

- Educational (degrees)
- Teaching (how long, where, what types of classes)
- What are your research interests in mathematics?

2) I'm going to ask you some questions about the MSMME program:

- Who is the program intended for?
- What students do you actually encounter in classes?
- What's the history of the program? From how it started to now
- What type of content are students exposed to? (how much math/math ed).
- What are the major goals of the program?
- Who designed the online components of the program?
- Do guidelines exist for online classes in the program? (or is it up to each individual instructor)

3) What were your initial experiences with online learning?

- Had you read research on it?
- Taken a class yourself?
- Just all of a sudden given the task to form a class online?
- Any mentors or were you the "leader" at MSU?

4) What beliefs do you hold about online learning in terms of :

- Learning effectiveness (does it enhance learning? Or not?)
- Pedagogy of teaching online (easier, harder, different in what ways)
- You said online is better than ftf is that just for this program or everything?
- MSU's online platform is ALN/text-based – how do you feel about other forms? ie. synchronous, video, etc.
- Mathematics classes in general being online –is it okay?

5) How do you typically set up online courses? Do YOU have general guidelines in designing an online course that YOU adhere to? Is it different in your ftf classes?

6) How would you define a "quality online discussion"?

7) How do you define higher order learning and/or critical thinking?

8) a. What are the usual types of tasks that you assign in your online classes – no specific examples (non-class specific)? ***Ask about posing problems

b. For each of these tasks, what do you see as the objective of the task?

c. Do you feel some tasks are more capable of pushing the students to think critically or at a higher level ? Which ones? Why?

d. Are tasks you design for online classes different than those you design for in-class? Why and how?

9) In terms of Math 522 and Math 533 as courses– what do you see as the primary differences between the two courses in terms of:

- Content
- Student base
- Level of difficulty

10)   Give me your overall impression of your experience in teaching Math 533 – so for instance if someone asked "how did the course go?"

- What would you change if you taught it again online? Why.
- Were there any surprises?
- List tasks here: ermo summary, student critique of ermo, investigations, discussions (pros/cons of nclb & hst, compare crt item classification), living lab (assessment tool brought to class), informative 10 pg article on nclb, hst, state

standards, postage stamp problem/living lab (do themselves then give to class to try, design rubric, talk about rubric, use to score), final paper (assessment plan)

---which tasks do you feel resulted in individual students engaging in critical thinking (that you could witness through writing, discussion, etc)? Is this what you expected when designing the tasks?

---which tasks do you feel resulted in students as a group engaging in critical thinking (social construction of knowledge)? Is this what you expected when designing the tasks?

11) Give me your overall impression of your experience in teaching Math 522 – so for instance if someone asked "how did the course go?"

- What would you change if you taught it again online? Why
- Were there any surprises?
- LIST tasks here: ermo summaries, math problems, application of math problems to the classroom (spin-off problems), websites, biography activity/Hodgkin article/ discussion on history in classroom, pan balancing/commensurable, analyzing proofs/thinking (kind of – pesky, pi), capsules/lesson plans, non-euclid application.

---which tasks do you feel resulted in individual students engaging in critical thinking (that you could witness through writing, discussion, etc)? Is this what you expected when designing the tasks?

---which tasks do you feel resulted in students as a group engaging in critical thinking (social construction of knowledge)? Is this what you expected when designing the tasks?

12) Overall, how would you compare the level of discussion that evolved in your Math 522 course compared to your Math 533 course?

- What factors contributed to the difference if there is one? (Students about same right? Content only? Design? Tasks?)

APPENDIX D

COGNITIVE PRESENCE CODING PROTOCOL

Phase	Code	Indicators	Socio-cognitive processes
Comments	*Co-1*	*Social/personal*	*-Non-academic comments not relevant to course content*
	Co-2	*Logistical/technical*	*-Explanations of non-participation*
	Co-3	*Affirmation/ acknowledgement*	*-"Pats on the back" without adding to t he content or depth of the discussion*
	Co-4	*Housekeeping*	*-Organizational tasks internal to course*
Triggering Event	TE-1	Recognizing the problem	-Presenting background info that culminates in a question

-understanding/clarifying problem |
| | TE-2 | Sense of puzzlement | -Asking questions

-Messages that take discussion in a new direction |
Exploration	Ex-1	Divergence within the online community	-Unsubstantiated contradiction of previous ideas
	Ex-2	Divergence within a single message	-Many different ideas/themes presented in one message
	Ex-3	Information exchange	-Personal narratives/descriptions/facts (not used as evidence to support a conclusion)
	Ex-4	Suggestions for consideration	-Author explicitly characterizes message as exploration-e.g. "does that seem about right?" or "am I way off track?"
	Ex-5	Brainstorming	-Adds to established points but does not systematically defend/justify/develop addition
	Ex-6	Leaps to conclusion	-Offers unsupported opinions
-Unsubstantiated agreement
	Ex-7	*Information request*	*Request for information and supplying the information*

Phase	Code	Indicators	Socio-cognitive Processes
Integration	In-1	Convergence-among group members Substantiated agreement	-Reference to previous message followed by substantial agreement e.g. "I agree because". -Building on, adding to other's ideas
	In-2	Convergence-within a single message	-Justified, developed, defensible, yet tentative hypotheses
	In-3	Connecting ideas, synthesis	-Integrating info from various sources-texts, articles, personal experience
	In-4	Creating solutions	-Explicit characterization of message as a solution by participant
	In-5	*Convergence through disagreement*	*-Substantiated contradiction that leads to deeper analysis*
Resolution	Re-1	Vicarious application to real world Testing solutions	None provided
	Re-2	Defending solutions	

Note. Adapted From "Critical thinking, cognitive presence, and computer conferencing in distance education," by Garrison et al. 2001, *American Journal of distance Education,15(1).*