HUMAN-CENTERED COMMUNICATION TECHNOLOGIES

TO ENHANCE TUTORING

by

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Human-Centered Communication Technologies to Enhance Tutoring

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(Abstract)

The goal of this research was to investigate communication media and feedback learning cues for tutoring. A macroergonomic perspective was used to identify three sociotechnical variables associated with tutoring assistance: problem analyzability, communication media, and learning feedback cues. A four-phase problem solving approach was used in all trials. The communication media consisted of collocated communication, email, a chatroom, and video teleconferencing. The learning feedback cue was a non-verbal mechanism for subjects to provide the tutor with immediate information about their understanding throughout the problem. Subjects participated in a total of eight trials over a four-week time period.

The analysis accuracy, process time, and user satisfaction indicated that the four-phase problem solving approach was not important in the interpretation of the results. In each problem-solving phase and for the overall tutoring process, technical performance (e.g., accuracy and speed of problem solving) and user satisfaction were measured to determine the most effective communication technology (or technologies) for tutoring students. The results of this study indicated that the accuracy was similar for all experimental conditions. However, the speed of problem solving was generally faster for audio-visual communication than text-based communication. In all phases, subjects were significantly more satisfied in conditions without feedback cues. And in general, satisfaction was higher in collocated communication and the chatroom compared to email; satisfaction was generally higher in collocated communication compared to video teleconferencing.

There was no evidence that computer-mediated communication improved the tutoring process. However, important design implications existed for tutoring systems with limited resources. Through computer-mediated communication, a single tutor could assist many students at one time. The chatroom appeared to be a condition that would be an effective communication medium for spatially dispersed tutoring. Although the tutoring process required significantly more time to complete using the chatroom compared to collocated communication, accuracy and satisfaction measures were similar between collocated communication and the chatroom.

Dedication

This thesis is dedicated to my family for their continued love, understanding, and patience.

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I would like to thank each of my committee members for their individual contributions and advice throughout this study. I learned a great deal about the research process through each one of you.

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A special word of thanks goes to several friends who had limitless resources from which I could create the learning feedback cues.

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Chapter 1 Introduction to Research

1.1 Background

Faculty involved in teaching and research have a difficult time meeting each and every student for personalized assistance. Students need to use other means of support outside the classroom such as tutoring. While tutoring centers exist on campus, many students have not used these resources to their advantage. There were several reasons why students did not use the tutoring center at Virginia Tech. Some students were frustrated by the amount of time they were forced to wait before a tutor became available; as a result they gave up on using the tutoring center (Van Aken, 1995). Other students cited the tutoring centers were not open when they actually did their homework, and many tutors only helped with freshman and sophomore classes (Van Aken, 1995). Another problem was freshmen did not know where to go for tutoring help. Anecdotally, students also complained tutoring was not located where they studied. Therefore they had to interrupt their studying to walk across campus to get help.

With modern human-centered communication technology, we can literally bring support, for example, tutoring, to the student where he or she studies and when the student requires assistance (Hendrick, 1995). One recent example of this is the electronic tutoring (email tutoring) in the College of Engineering at Virginia Tech. However, using computer-mediated communication technology has not been experimentally tested to determine which types of technology are effective media for students to use for tutoring. Much research has been conducted in organizations to determine effective ways to meet electronically for decision making and problem finding (Hiltz, Johnson, and Turoff, 1986; Jarvenpaa, Rao, Huber, 1988; Pinsonneault and Kraemer, 1990; Nunamaker, Dennis, Valacic, Vogel, and George, 1991; McLeod, 1992; Turoff, Hiltz, Bahgat, and Rana, 1993; Hart, Svenning, and Ruchinskas, 1995). Some research on computer-mediated communication has been conducted in classrooms (Hunter, 1990; Leidner and Jarvenpaa, 1993; Alavi, 1994; Briggs, Ramesh, Romano, Latimer, 1994; Durrani, Husain, Khawaja, and Yaqub, 1995; Lawrence, 1995; Flur, Lockhart, and Yalamanchili, 1996; Steeples, Unsworth, Bryson, Goodyear, Riding, Fowell, Levy and Duffy, 1996; Waxman and Huang, 1996). Building on this research, we can determine effective communication configurations for tutoring.

1.1.1 Sociotechnical Systems Theory

Macroergonomics is one perspective that can be used to study computer-mediated communication for the purpose of tutoring. The research, development, and application of the human/organization/environment/machine interface are the focus of macroergonomics (Kleiner, 1996). This approach is "a top-down approach to system design based on a sociotechnical perspective" (Brown, Hendrick, Imada, and Kleiner, 1997). In macroergonomics, a top-down approach begins by identifying the appropriate sociotechnical system variables and determining how these variables will affect the design of the work system and processes. The ultimate goal of macroergonomics is to have an optimized work system at the macro- and micro-ergonomic level. By applying the macroergonomic perspective to a tutoring system, sociotechnical system variables were identified and tested to determine the effect on the work system and people using the system.

A sociotechnical system is a bounded, purposeful enterprise comprised of people whose purpose is to transform inputs into outputs (Taylor and Felten, 1992). The system is open in that it exists in and is influenced by an environment (Hendrick, 1991). A tutoring system loosely fitted into this definition of sociotechnical system. Figure 1.1 shows some components of a tutoring system. A tutor worked with a student for a short period of time for the purpose of learning. Therefore ideas and concepts were

transformed into useful knowledge. In this study, the ultimate purpose of tutoring was to develop solutions to problems. Tutoring existed within several identifiable external environments, for example, the college of engineering, the university, and the extended community.

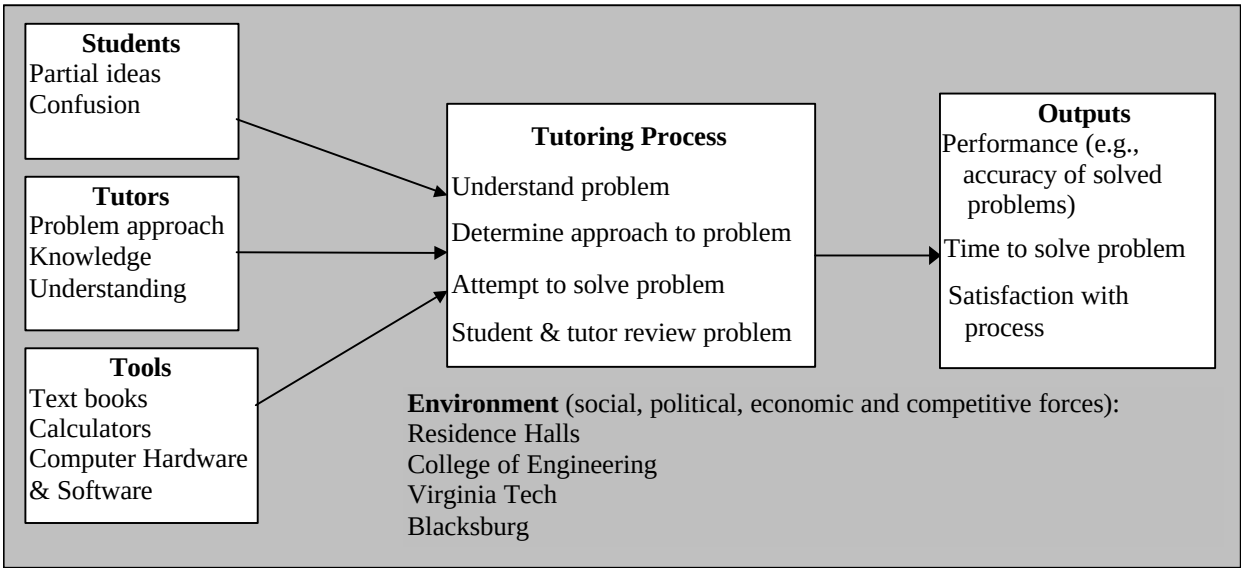

Figure 1.1 Components of a tutoring system

In sociotechnical theory, the system is broken into three subsystems: technological, personnel, and job design (Hendrick, 1986). The technological subsystem contains the tools, technology, work rules, and processes that convert system inputs into outputs (Hendrick, 1986). In tutoring, the technological system included the process used to solve the problem, the technology used to facilitate communication and any tools that might be used, for example, calculators or computer software. The personnel subsystem refers to the way that people in the system perform tasks. Dimensions of the personnel subsystem include social interactions, level of education and training, psycho-social characteristics, for example, cultural factors and preferences for processing information, and communication (Hendrick, 1984). In tutoring, the personnel subsystem included the students and tutors and their individual backgrounds. Job design refers to the structure of the organization. For tutoring, the design could have been either one-on-one tutoring or group tutoring and occurred either collocated or spatially dispersed. These subsystems operate in the context of an external environment. The environment contains competitive, economic, political, and legal force, just to name a few (Kleiner, 1996). For example, in tutoring, the environment included the residence hall, department, and university's environment as well as the community of Blacksburg's environment.

The three major principles behind sociotechnical system theory are 1) joint causation, 2) joint optimization, and 3) joint design (Hendrick, 1986).

> Joint causation: A characteristic of sociotechnical systems is that they are open systems. Therefore, the environment will influence the personnel and technological subsystems. Real change usually occurs through the personnel subsystem because the technological subsystem tends to be fixed. The personnel subsystem is much more adaptable to changes than is the technological environment (Hendrick, 1986).
>
> Joint optimization: If the personnel or technological subsystem were to be optimized, the result would be a sub-optimized system. This is in part due to joint causation. Therefore, changes to one subsystem cannot drive changes to the other subsystem.

Joint design: Joint optimization is achieved through joint design. The requirements of each subsystem are considered along with the influence of the environment in designing the system.

1.1.2 Problem Solving

Organizations today want specific skills from the entry-level engineer. Problem solving skills and teamwork skills are two of these characteristics (Katz, 1993). Unfortunately, many organizations believe universities are not producing graduates with these skills. Problem solving skills can be designed into a tutoring program to help students develop a competency in these areas.

1.2 Problem Statement

Universities provide tutoring to help the academic achievements of students. With a macroergonomic perspective, important personnel, technological, and environmental variables were identified for optimal work system design. Human-centered communication technology and feedback learning cues were explored to determine the optimal configuration for tutoring students.

This research focused on macroergonomic issues associated with virtual communication. For this reason, user satisfaction was one of the outcome variables that helped to determine the optimal condition for tutoring. Microergonomic issues associated with the communication technology and feedback learning cue were outside of the scope of this research. The software and hardware setups were typically chosen for reasons of practicality. At Virginia Tech, Euroda Light™ is the commonly used email communication software. In addition, students have access to this software free of charge. The chatroom software chosen was freeware downloaded from Internet. And the video teleconferencing software used was the most recent working version available that was compatible with the hardware.

1.3 Research Objectives

Much of the research on tutoring focused on the process of tutoring and whether or not tutoring was an effective method to improve student learning (Ehly and Bratton, 1981; Cohen, Kulik, and Kulik, 1982; De Volder, 1982; Schmelzer, Brozo, and Stahl, 1985; Fantuzzo, Riggio, Connelly, and Dimeff, 1989; Greenwood, Delquadri, and Hall, 1989; Hartman, 1990; House and Wohlt, 1990; Yunker, 1991; Franklin, Griffin, and Perry, 1994; Gyanani and Pahuja, 1995; Hock, Schumaker, and Deshler, 1995). The literature on tutoring did not show tutoring had been designed based on sociotechnical systems or macroergonomics theory. Therefore, by approaching tutoring from a macroergonomic perspective, new learning might be discovered. For the most part, tutoring design appeared to be based in learning theory (Cohen et al., 1982; Schmelzer et al., 1985; Franklin et al., 1994; Hock et al., 1995). In addition, very little research appeared to have been conducted that focused on communication technology in the context of tutoring. Similarly, little research appeared to have been performed that investigated students using technology to send feedback learning cues to aid the tutoring process. However, McKendree (1990) did show that feedback was critical for evaluation purposes in learning. The objectives for this research were to:

1. Determine if feedback cues helped students in the tutoring process

2. Determine which type of computer-mediated communication technology students should use for the purpose of tutoring
3. Learn if feedback cues in conjunction with computer-mediated communication technology could improve the student's tutoring process
4. Learn if students were satisfied using computer-mediated communication technology for tutoring

1.4 Conceptual Model

To understand how a tutoring system fit within a large university system, a flow diagram of a student's progress through a university is shown in Figure 1.2. Most students enter the university directly from high school where they were influenced and counseled by parents, teachers, guidance counselors, and friends to apply to college. When students are accepted into a college, their decision to attend a particular school is still influenced by their support community. Once students arrive at college, they go through a transformation process that, in theory, prepares them for a job upon graduation. While in school, students still have family and friends for support; however, they are typically separated by distance. Therefore, students must work to create a new support system. Some colleges have programs in place, for example, peer mentoring, tutoring, and advising. As students become mature in their educational process, they also develop support relationships with faculty and, potentially, industry members (from coop positions or internships). Before graduating, most students begin to interview for jobs. The companies they interview with and the jobs they accept are also influenced by their support system. Upon graduation, students become part of the professional work force. In the work force, they continue to have support. Their support comes from co-workers, professional societies, and new family members, for example, spouses in addition to some of the old contacts that are maintained.

In this conceptual model, the method for tutoring was based on the problem solving process. Problem solving was used because it is an important skill for engineers to have (Katz, 1993). Currently, problem solving is one of engineering students' weaknesses as reflected by their grades in classes oriented towards problem solving (OMEP, 1996). Problem solving has a well-developed model. Although there are many different models for problem solving, most of the models have the same basic components: first the problem must be understood, second the approach to the problem is planned, third the plan is carried out, and finally the complete solution is studied (Polya, 1957).

Mastering problem solving should help to improve the performance for students who were previously unorganized in their problem solving approach. This approach can assist tutors to easily identify exactly what the student does and does not understand. Therefore, the tutor could focus on those concepts or skills the student lacked. In addition, by writing out details in a test environment, the student actually helped the tutor to know whether or not the student understood the concepts.

In tutoring, the environment in which students exist was the university environment. The students worked either individually or in a group with a tutor. The personnel subsystem consisted of students and feedback learning cues. Feedback cues were a method of communication that allowed students to give the tutor non-verbal feedback on their level of comprehension of the topic being explained. The intent was that non-verbal feedback is not as threatening as verbal feedback (Ashford and Cummings, 1983). In addition, long and unhelpful tutoring sessions were avoided because students let the tutor know immediately when they understood the material. In the technological subsystem, the technology used for the students to

communicate with the tutor was of interest. The types of communication technology explored in this study included email, chatroom, and video teleconferencing.

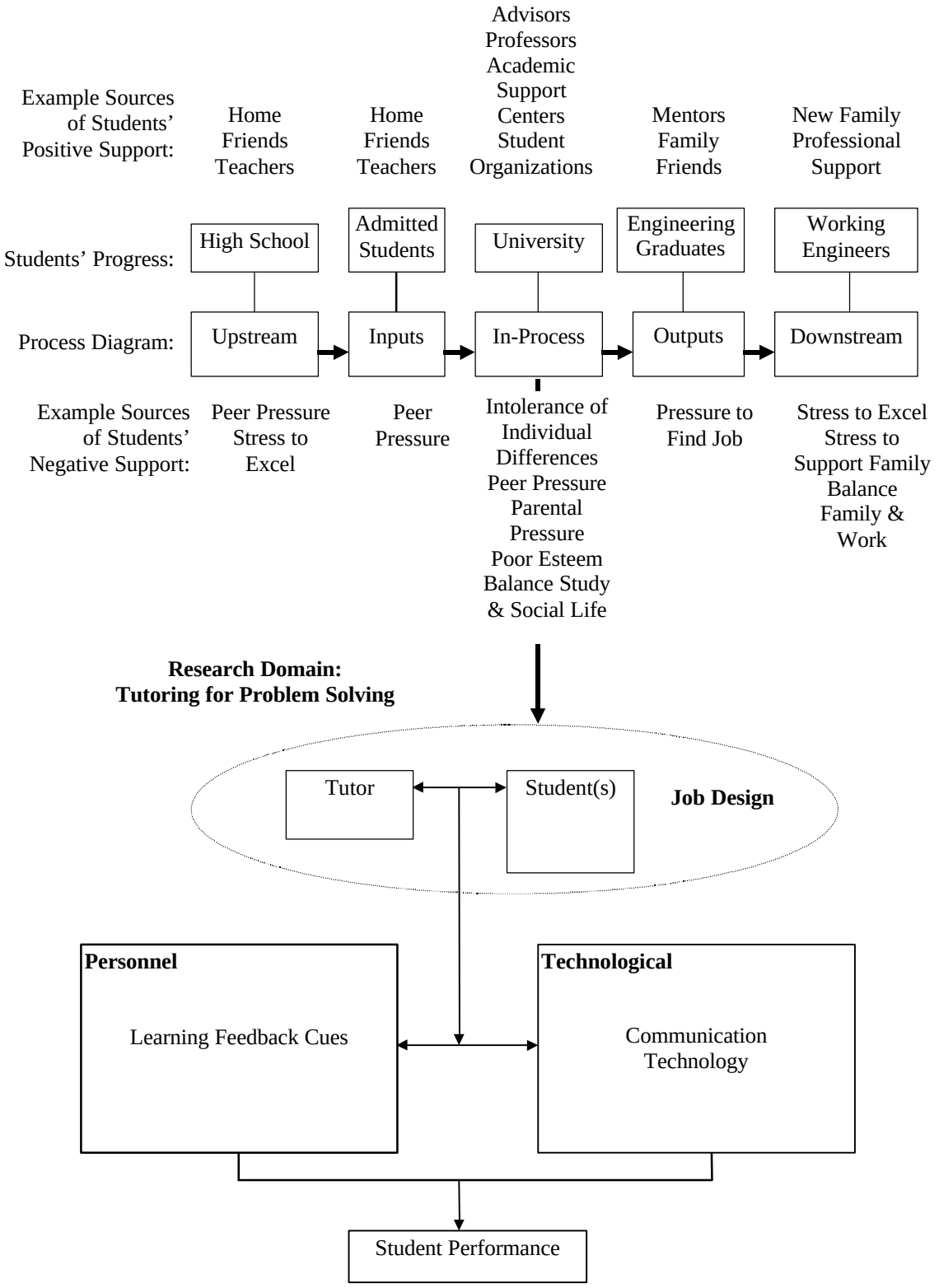

Figure 1.2 Conceptual model

1.5 Research Questions and Hypotheses

The questions and hypotheses this research addressed are presented in this section. The independent variables in these hypotheses were presented in the conceptual model. The purpose was to determine the independent variables' effect upon students performing problem solving tasks during tutoring. The specific task is discussed in Section 1.6 and measures of performance are discussed in Section 1.7. Note that, in the following hypotheses, the term "text-based" refers to both email and chatroom communication technology and the phrase "audio-visual linked" refers to collocated and video teleconferencing communication technology.

1.5.1 Effect of Computer-Mediated Communication Technology and Feedback Cues on Performance

Research Question 1: How will computer-mediated communication technology affect the performance of students?

Performance of students for this research was defined as the accuracy of the student's work. The students' mathematics instructor acted as the expert and rated the accuracy of each phase on a ten-point scale for a total of forty possible points.

From the literature, computer environments affected variables such as performance. Some researchers found the overall quality of the task was higher with the use of group support systems (GSS) (McLeod, 1992). Some researchers found GSS helped increase the number of alternatives and ideas generated (Pinsonneault and Kraemer, 1990).

In the control condition, collocated students had direct access to the tutors and therefore benefited from all of the nuances of non-verbal interactions. Similarly, in the video teleconferencing condition, students and tutors were able to speak with and see one another. Anonymity was another issue discussed in the literature. More approaches to problems were found when people were not associated with a name, social position, gender, race, or appearance (Dubrovsky, Kiesler, and Sethna, 1991). Students who were comfortable working directly with other people might perform better with audio-visual linked communication, while students who were uncomfortable around other people might prefer the individualist style of text-based communication. The student's comfort level might influence their performance because the student's discomfort might become a source of distraction.

The literature supported participants using computer-mediated communication technology were more focused on their task than those who were collocated (McLeod, 1992). Time lags in communication negatively influenced the outcome of tasks (Smith and Vanecek, 1989). People became frustrated by the lack of an immediate response (Smith et al., 1989). Time lags could be a problem with email tutoring.

Phase 1: Understand the Problem

Research Hypothesis 1a: There will not be a difference between the levels of technology in the students' demonstration of understanding the problem.

Phase 2: Plan the Approach

Research Hypothesis 1b: Students will have higher performance when they use audio-visual linked tutoring than when they use text-based tutoring.

Phase 3: Implement the Plan (Solve the Problem)

Research Hypothesis 1c: The students' accuracy of their solution will vary for the technology levels. If the levels of technology are different, then the solutions using video teleconferencing will have a higher level of accuracy than chatroom followed by collocated, and email.

Phase 4: Review the Problem Solution

Research Hypothesis 1d: Students will achieve higher accuracy on their solution review with text-based tutoring than with audio-visual linked tutoring.

Overall

Overall accuracy will be found by summing the accuracy for each phase.

Research Hypothesis 1e: Student's' accuracy will be affected by the technology level.

Research Question 2: How will access to a feedback cue affect the performance of students?

Feedback is an important mechanism for evaluation (Ashford et al., 1983). However, the process of giving negative feedback can be very intimidating (Ashford et al., 1983). A feedback cue was a non-threatening way for students to let their tutor know when they did not understand the concepts being tutored.

Phase 1: Understand the Problem

Research Hypothesis 2a: When students have access to the feedback cue they will have higher performance compared to when they do not have access to the feedback cue.

Phase 2: Plan the Approach

Research Hypothesis 2b: Students with access to the feedback cue will have higher scores than those without the feedback cue.

Phase 3 Implement the Plan

Research Hypothesis 2c: Students will have similar scores in the solving phase both with and without access to the feedback cue.

Phase 4: Review the Problem Solution

Research Hypothesis 2d: Students will have higher scores in the problem review when they have access to the feedback cue than when they do not have access to the feedback cue.

Overall

Research Hypothesis 2e: Students will have higher overall accuracy scores as a result of using the feedback cue compared to not using the feedback cue.

Research Question 3: How will the interaction between feedback cue level and technology level affect students' performance?

Feedback is important when communication is inhibited by technology. For example, some students rely heavily on nonverbal cues that cannot be seen when using email (Shade, 1989). Video

teleconferencing typically only showed the other person's head and shoulders and not hand motions that might contain valuable information, while text-based communication did not allow the students and tutor to see each other for nonverbal information.

Phase 1: Understand the Problem

Research Hypothesis 3a: When students do not have access to feedback cues in text-based communication the scores will be lower than when they use text-based conditions with feedback cues. When they use audio-visual linked communication, the scores will be higher without feedback cues.

Phase 2: Plan the Approach

Research Hypothesis 3b: Students will have higher accuracy scores in audio-visual linked tutoring than in text-based tutoring when they do not have access to feedback cues. Students will receive higher accuracy scores in text-based tutoring than in audio-visual linked tutoring when they have access to feedback cues.

Phase 3 Implement the Plan

Research Hypothesis 3c: Students will receive higher accuracy scores in audio-visual linked tutoring than in text-based tutoring when they do not have access to feedback cues. Students will receive higher accuracy scores in text-based tutoring than in audio-visual linked tutoring when they have access to feedback cues.

Phase 4: Review the Problem Solution

Research Hypothesis 3d: Students will receive higher accuracy scores in audio-visual linked tutoring than in text-based tutoring when they do not have access to feedback cues. Students will receive higher accuracy scores in text-based tutoring than in audio-visual linked tutoring when they have access to feedback cues.

Overall

Research Hypothesis 3e: Students will receive higher accuracy scores in audio-visual linked tutoring than in text-based tutoring when they do not have access to feedback cues. Students will receive higher accuracy scores in text-based tutoring than in audio-visual linked tutoring when they have access to feedback cues.

1.5.2 Effect of Computer-Mediated Communication Technology and Feedback Cues on Process Time

Research Question 4: How will computer-mediated communication affect the process time for tutoring?

Process time was another variable used to assess computer environments. Some researchers found the time to complete the task increased in a text-based, computer-mediated environment (Hiltz, Johnson, and Turoff, 1986; Siegel, Dubrovsky, Kiesler, and McGuire, 1986; McLeod, 1992; Weeks and Chapanis, 1976). Studies that compared video teleconferencing and face-to-face communication did not find significant time differences (Ochsman and Chapanis, 1974; Weeks et al., 1976; Kinney and Dennis, 1994).

Phase 1: Understand the Problem

Research Hypothesis 4a: Students will spend more time understanding the problem using text-based tutoring than using audio-visual linked tutoring. However, email will be where students spend the most time.

Phase 2: Plan the Approach

Research Hypothesis 4b: Students will spend more time in the planning phase using text-based communication than using audio-visual linked communication. Email will be the communication media in which students take the longest amount of time.

Phase 3: Implement the Plan (Solve the Problem)

Research Hypothesis 4c: Students will spend more time in the implementation phase using text-based tutoring than using audio-visual linked tutoring. Again, students using email will take the most time.

Phase 4: Review the Problem Solution

Research Hypothesis 4d: Students will spend more time in the revisiting phase using text-based tutoring than audio-visual linked tutoring. Students will take the longest time when they use email.

Overall

Research Hypothesis 4e: Students will spend significantly different amounts of time solving problems using the different levels of technology. The configuration that will take the most time is email.

Research Question 5: How will access to a feedback cue affect the process time for tutoring?

The number of cues present in a communication process were found been found to influence the time it takes to complete a task (Kinney et al., 1994). Therefore, allowing the tutor to know immediately if the student is confused or if they understand everything might reduce the process time.

Phase 1: Understand the Problem

Research Hypothesis 5a: Students will spend less time in the understanding phase when using the feedback cue.

Phase 2: Plan the Approach

Research Hypothesis 5b: Students will spend less time in the planning phase when using the feedback cue.

Phase 3 Implement the Plan

Research Hypothesis 5c: The feedback cue will not affect the time spent in the implementation phase.

Phase 4: Review the Problem Solution

Research Hypothesis 5d: Students will spend less time in the revisiting phase when they use the feedback cue.

Overall

Research Hypothesis 5e: Students will spend less time to complete the task when using the feedback cue.

Research Questions 6: How will the interaction between feedback cue and technology level affect students' process time?

In text-based communication, the feedback cue might speed the process by providing the tutoring with immediate feedback. In email communication, immediate feedback can be important because email is a form of asynchronous communication.

Phase 1: Understand the Problem

Research Hypothesis 6a: When students do not have access to the feedback cue, they will spend more time in text-based tutoring than in audio-visual linked tutoring. However, when students have access to feedback cues, the time in text-based tutoring should become shorter.

Phase 2: Plan the Approach

Research Hypothesis 6b: When students do not have access to feedback cues, they will spend more time in text-based tutoring than in audio-visual linked tutoring.

Phase 3: Implement the Plan

Research Hypothesis 6c: Students will spend more time in the implementation phase without the use of feedback cues while using text-based tutoring than using audio-visual tutoring.

Phase 4: Review the Problem Solution

Research Hypothesis 6d: Students will spend more time in this phase using text-based tutoring than in audio-visual linked tutoring when they do not have access to feedback cues.

Overall

Research Hypothesis 6e: Students will reduce the time it takes to complete the task using text-based tutoring when they have access to feedback cues. Feedback cues will not affect the time it takes to complete the task in collocated and video teleconference tutoring.

1.5.3 Effect of Computer-Mediated Communication Technology and Feedback Cues on User Satisfaction

Research Question 7: How will computer-mediated communication affect how students perceive the tutoring process?

Smith and Vanecek (1989) found satisfaction was lower in a text-based, computer-mediated communication than in face-to-face communication. Computer-based support has a negative side; it tends to be impersonal. Therefore, even though students were able to communicate with tutors without having to be in the same place, information might haven been lost in the process. Students may have depended on body language to communicate (Shade, 1989). If the tutor could not see the students' body language, they may have missed important cues that communicated either understanding or a lack of understanding. Similarly, vocal inflections were good cues to judge how well problem explanations were understood.

Satisfaction will probably be a function of the ease with which the technology allows the students to portray their ideas and questions to the tutors. Therefore, technology issues are not a factor in the collocated level. Students might become frustrated by email communication because of the time lag (Smith et al., 1989).

For all phases of the problem solving process and for the overall process, the hypothesis regarding the students' satisfaction with the technology is the same and is as follows:

Research Hypotheses 7a-e: Students will have the same level of satisfaction with video teleconference and collocated tutoring. However, the audio-visual linked tutoring will have higher satisfaction than chatroom followed by email tutoring.

Research Question 8: How will feedback cues affect how students perceive the tutoring process?

Giving and receiving feedback can be perceived as threatening (Ashford and Cummings, 1983). The intent of feedback cues was to reduce the risk involved with students asking questions. Students may need to give feedback to the tutor; however students might be too intimidated to give the appropriate feedback. Another issue is that students might perceive the feedback cues to be more trouble than they are worth. On the other hand, the cues might represent an adequate nonverbal method for the students to give immediate feedback to the tutor. When feedback from the student to the tutor is missing the communication process might be delayed (O'Conaill, Whittaker, and Wilbur, 1993). These delays might result in frustration.

Phase 1: Understand the Problem

Research Hypothesis 8a: Students will have a higher level of satisfaction when they have access to the feedback cue as opposed to when they do not have access to feedback cues.

Phase 2: Plan the Approach

Research Hypothesis 8b: Students will have a higher level of satisfaction with the feedback cue in the planning phase.

Phase 3 Implement the Plan

Research Hypothesis 8c: The feedback cue will not affect students' satisfaction in the implementation phase.

Phase 4: Review the Problem Solution

Research Hypothesis 8d: Students will have a higher level of satisfaction with the feedback cue in the revisiting phase.

Overall

Research Hypothesis 8e: Students will have a higher level of satisfaction with the feedback cue.

Research Questions 9: How will the interaction between feedback cue level and technology level affect user satisfaction?

Phase 1: Understand the Problem

Research Hypothesis 9a: Students will have higher levels of satisfaction when they have access to feedback cues in text-based tutoring than in audio-linked tutoring. Feedback cues will not affect satisfaction in video teleconference tutoring.

Phase 2: Plan the Approach

Research Hypothesis 9b: Students will have higher levels of satisfaction when they have access to feedback cues in text-based tutoring than in audio-linked tutoring. Feedback cues will not affect satisfaction in video teleconference tutoring.

Phase 3 Implement the Plan

Research Hypothesis 9c: Students will have higher levels of satisfaction when they have access to feedback cues in text-based tutoring than in audio-linked tutoring. Feedback cues will not affect satisfaction in video teleconference tutoring.

Phase 4: Review the Problem Solution

Research Hypothesis 9d: Students will have higher levels of satisfaction when they have access to feedback cues in text-based tutoring than in audio-linked tutoring. Feedback cues will not affect satisfaction in video teleconference tutoring.

Overall

Research Hypothesis 9e: Students will have higher levels of satisfaction when they have access to feedback cues in text-based tutoring than in audio-linked tutoring. Feedback cues will not affect satisfaction in video teleconference tutoring.

1.5.4 Optimal Solution for Tutoring Process

Research Question 10: What is the optimal configuration for tutoring and does this configuration depend on the phase?

This gets to the real underlying question of this research. How should tutoring be set up to facilitate communication between tutors and students? Is too much information lost by current communication technology? Does the level of technology depend on the type of problem structure and type of communication mode? Does the feedback cue provide enough information to fill in the gaps when there is no visual contact? Does the combination of phase, level of communication technology and feedback cue access affect accuracy, process time, and/or user satisfaction?

The optimal condition for students might be a series of tradeoffs (Trist, 1978). The condition with the highest performance might not be aligned with the condition with the highest user preference. Even though students might be unsatisfied with the technology, they may find the technology very convenient and prefer the informality. In addition, each phase requires different levels of information transfer. This might cause different configurations to be optimal for each of the different phases.

Another consideration is the individual differences between students. Students who prefer working with people might enjoy the audio-visual linked tutoring more than text-based tutoring. However, some students might be intimated by working in front of another person; they prefer to work alone. This type of student might prefer text-based tutoring to audio-visual linked tutoring. Another difference to consider is the students' level of competence with information and concept being tutored. Students that are familiar with the subject might not need constant attention; therefore, they might prefer text-based tutoring to audio-visual linked tutoring. On the other hand, students' who lack familiarity with the subject might need more constant attention from the tutor which audio-visual linked tutoring allows.

Hypothesis 10a: The optimal solution will be different for at least one of the phases.

Hypothesis 10b: The optimal solution will be video teleconferencing with feedback cues.

1.5.5 Tutor Perceptions

Research Question 11: How will the tutor perceive his participation in the system? Which levels of technology and feedback cue will have the highest level of satisfaction for the tutor?

Another aspect of this research is to find out if the tutor perceived his participation to be worthwhile. Tutors may have a high level of intrinsic satisfaction based on being able to help a student. Even though tutors and students are not collocated, tutors should maintain satisfaction by being able to see and hear students and dialogue with them to solve problems. In email tutoring, tutors might lose the spontaneous feedback that is available with the other conditions. However the feedback cue should facilitate the tutor's ability to assist the student. Since the feedback is continuous, the tutor's satisfaction might be effected in the text-based conditions.

Research Hypothesis 11: The tutor's satisfaction will vary based on the level of technology and feedback cue. The tutor will have the highest level of satisfaction in video teleconference tutoring with feedback cues followed by chatroom with feedback cues, chatroom without feedback cues, collocated without feedback cues, collocated with feedback cues, video teleconferencing without feedback cues, email with feedback cues, and email without feedback cues.

1.5.6 Summary of Hypotheses

By answering each of these research questions, a configuration should be determined for developing an effective (optimal) tutoring system for students. Based on sociotechnical theory, the results might be a series of tradeoffs between personnel and technological dependent variables (Trist, 1978). For example, the optimal level of technology as defined by the output may not be the technology level students (and tutor) prefer. Table 1.1 is a summary of all of the hypotheses for research questions 1 through 9. Lowest, low, high, and highest represents expected differences between the conditions. When significant differences were not expected between experimental conditions the level expected is given the same label. For example, when collocated and video teleconference tutoring were not expected to be significantly different, but they were expected to be higher than chatroom followed by email the labeling would be high for both collocated and video teleconference, low for chatroom and lowest for email.

Table 1.1 Summary of research hypotheses (not including interactions)

	Feedback Cue		Technology			
	No Cue	Cue	Collocated	Email	Chatroom	Video Teleconferencing
Accuracy						
Phase 1	low	high	same	same	same	same
Phase 2	low	high	high	low	low	high
Phase 3	same	same	low	lowest	high	highest
Phase 4	low	high	low	high	high	low
Overall	low	high	low	lowest	high	highest
Process Time						
Phase 1	high	low	low	highest	high	low
Phase 2	high	low	low	highest	high	low
Phase 3	same	same	low	highest	high	low
Phase 4	high	low	low	highest	high	low
Overall	high	low	low	highest	high	low
User Satisfaction						
Phase 1	low	high	high	lowest	low	high
Phase 2	low	high	high	lowest	low	high
Phase 3	same	same	high	lowest	low	high
Phase 4	low	high	high	lowest	low	high
Overall	low	high	high	lowest	low	high

1.6 Operational Model

Based on the key components of sociotechnical theory, Figure 1.3 is the operational model used in this study. The environment included that of the University and the College of Engineering. The personnel subsystem consisted of engineering students and an engineering tutor. Feedback cues were part of the personnel subsystem because they represented the students' learning process. In addition, one of the intents was to remove the fear sometimes caused by asking questions. The job design for tutoring consisted of one student and one tutor. The technological subsystem's independent variable was the level of technology: collocated, email, chatroom, and video teleconferencing.

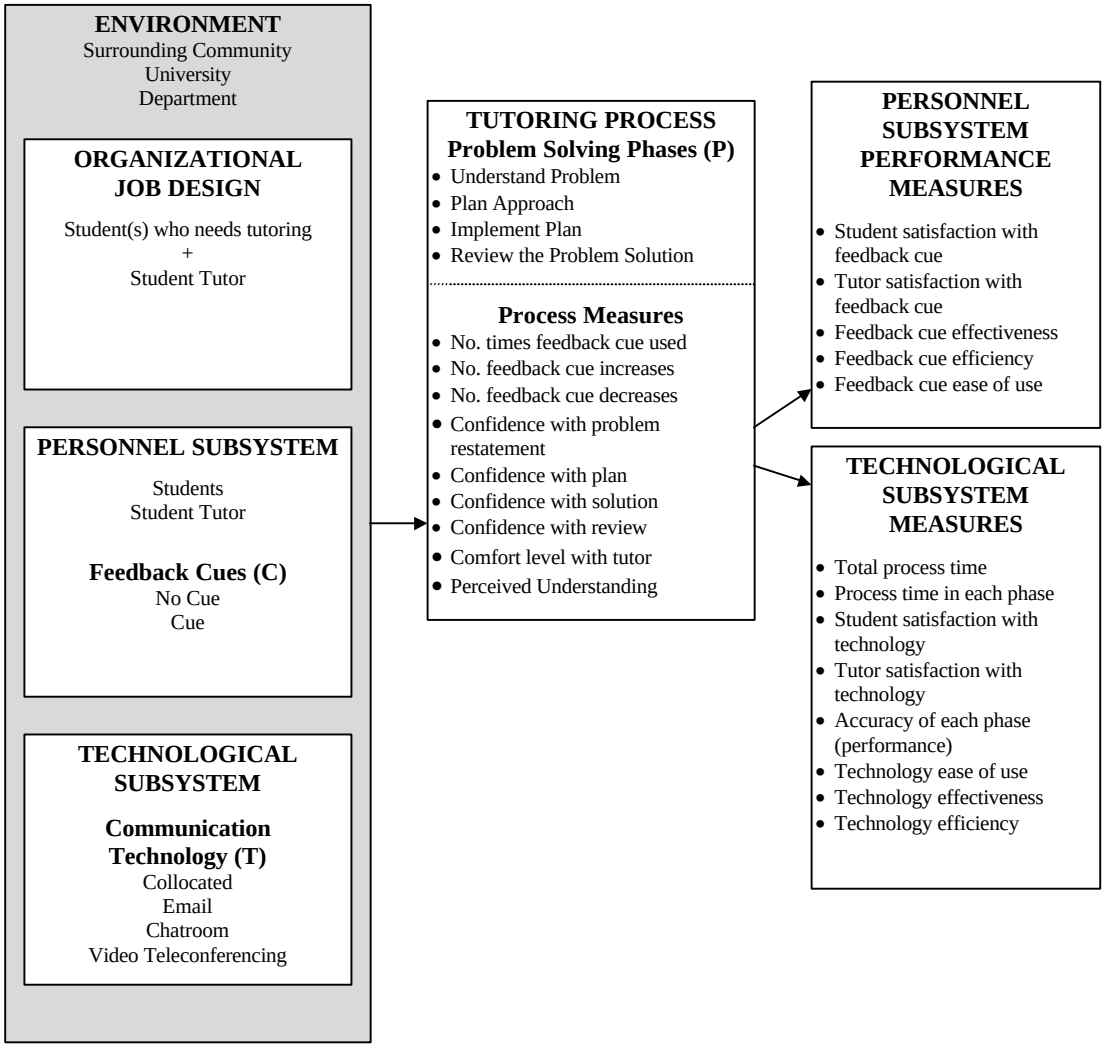

Figure 1.3 Operational model

1.6.1 Independent Variables

As mentioned before, Phase (P), Technology (T) and Feedback Cues (C) were the three independent variables. Phase (P) referred to the different stages of a problem solving method (Polya, 1957).

Phase 1, Understand the Problem (P_1): In this phase, students read the problem and became familiar with information provided. Students demonstrated understanding the problem by restating the problem in their own words and using figures or diagrams to portray the given information.

Phase 2, Plan the Approach (P_2): Once students understood the problem, they planned the approach they used to solve the problem. Students determined the relevant information they needed to solve the problem, what they needed to solve for, what equations they needed, and how they would actually accomplish solving the problem.

Phase 3, Implement the Plan (Solve the Problem) (P_3): In this phase, students followed their plan to solve the problem. The outcome of this phase was the solution.

Phase 4, Review the Problem Solution (P_4): In this phase, the tutor led the student through the previous three phases and asked the student to explain what they did and why. If the solution was not correct, they attempted to determine what went wrong. If the solution was correct, they explored other potential ways to solve the problem (when possible).

Technology (T) referred to the different levels of communication media, which included:

Collocated (T_1): Communication occurred at the same time in the same place. This is often referred to as face-to-face communication. In collocated communication, there was rich information. Individuals could give and receive immediate feedback. In addition, nonverbal cues were readily available.

Email (T_2): Communication occurred at different times and in different places. It was text-based communication that occurred through the use of a computer. Individuals sent and received messages at their convenience.

Chatroom (T_3): Communication occurred at the same time but in different places. This was a continuous on-line discussion that was text-based.

Video Teleconferencing (T_4): Communication occurred at the same time in different places. However, the people communicating had audio-visual contact with the other people involved. In addition they had access to text-based communication aids.

Feedback learning cues (C) were a symbolic representation of the students' level of understanding, which facilitated the students and tutor's communication. Students had access to three symbols that represented three levels of understanding, for example, high, medium, and low. Through feedback learning cues the tutor could quickly assess the student's understanding of the material. The two levels of the feedback cues were no learning feedback Cue (C_1) and the presence of the learning feedback cue (C_2).

1.6.2 Dependent Variables

In this study there were two kinds of dependent variables: objective and subjective variables.

1.6.2.1 Objective Variables. Objective measures were developed to determine how well the tutoring system was performing. From sociotechnical theory, variables from both the personnel and technological subsystems were measured to determine the optimal design (Trist, 1978). The theory goes further to suggest that the optimal design will result from a series of tradeoffs between the personnel and technological systems. Data was collected by 1) the expert who analyzed the task for accuracy and 2) the tutor who recorded the time it took for a subject to complete each phase (process time). The videotape was used to help the researcher capture the any work conducted during the tutoring process that was not recorded on the worksheet.

The objective variables, accuracy and process time, were collected in each phase and in the overall tutoring process. To determine the overall accuracy, the accuracy for each phase was summed. Similarly, the overall process time was calculated by summing the process times in the individual phases.

1.6.2.2 Subjective Variables. Subjective variables are measures of opinion. The subjects rank ordered satisfaction, ease of use, efficiency, effectiveness, and comfort level with each experimental condition for each phase and for the overall process after they completed all experimental conditions. In addition to the subjects' satisfaction, data was collected about the tutor's perceptions of the technology and feedback cues. In addition to the ranked orders, satisfaction, ease of use, efficiency, and effectiveness were also measured after each phase using a Likert-type rating scale. User satisfaction is often used as an aggregate of the subjective measure (Olaniran, 1995, 1996). Therefore, in this study, satisfaction was the key subjective variable.

Two subjective variables were collected that might relate to the task accuracy. Subjects' perception of how well they worked the math problem (perceived accuracy) was collected. In addition, subjects were asked about how well they understood their work for each phase. For example, the output for Phase 1 was a problem restatement. The subject reflected on how well they understood their problem restatement.

1.7 Premises and Delimitations

This section refined the scope of this study by stating all assumptions, premises, and delimitations. Statements that did not have research to back them up as true were assumptions. Premises identified the conditions of this research. Delimitations identified what was not covered in this research.

Assumptions

- Students and tutors could be trained to use the technology if they were not currently familiar with it.
- Tutors could be trained to follow the problem solving model method for tutoring if they were not currently familiar with it.
- Individual differences in subjects' mathematics ability were representative of a typical pre-calculus class.

Premises

- Joint optimization is desired for the design of tutoring systems.
- Students will continue to seek tutoring as a source of academic help.

Delimitations

- Individual student learning as a result of tutoring was not considered.
- Contextual variables related to subjects with respect to sociological or psychological variables, for example, gender, motives, and age (other than subjects must be at least 18 years of age), were not considered.
- Specific types of computer hardware and software products were not considered in this research – the products used to permit each type of computer-mediated communication level were chosen either because of availability or accessibility.
- The micro-ergonomic issues associated with the communication media and feedback learning cue were not considered.

1.8 Justification for this Research

Many researchers have shown support services improved students' performance (Hiemenz and Hudspeth, 1993; Blanc, DeBuhr, and Martin, 1983). Of the methods described in the literature for providing students with academic assistance, tutoring seemed to be an effective method for helping a large number of students. In addition, the access to technology is growing. At Virginia Tech, all entering engineering students are required to have a personal computer. Part of the package provided to the students through the school included equipment that allows for computer-mediated communication. Specifically, email software, a sound card, and speakers are included in the package. In addition, several software corporations provide freeware on the Internet for chatrooms. In the near future, the software and hardware required for video teleconferencing might be included in the freshman package.

Technology is an enabler for bringing tutoring to students where they prefer to study, in the dormitories, library, or student centers. Currently, the College of Engineering provides both collocated and email tutoring. However, with the availability of chatrooms and soon to be available video teleconferencing, research needed to be conducted to determine which method was the best for tutoring. This research was supported through the Office of Minority Engineering Programs because of their interest in determining the best method of tutoring students. The tutor used in this study was funded through the Southeastern University and College Coalition for Engineering Education (SUCCEED), funded by the National Science Foundation, because of their interest in the results of the video teleconferencing portion of this research.

Chapter 2 Literature Review

The purpose of this chapter was to review the current body of literature in macroergonomics, computer-mediated communication, tutoring, and problem solving that applied to this study.

2.1 Introduction

A unique proposed approach to this problem is designing human-centered communication technologies for tutoring with a macroergonomic perspective (Hendrick, 1995). Human-centered refers to work design where using a person is justified as opposed to convenient. Therefore, "tasks are designed to make full use of human skills and to compensate for human limitations." (Hendrick, 1995; p. 762) The macroergonomic perspective can help with understanding the environment by identifying important social, technical, and job design variables for the design of a tutoring system (Hendrick, 1986).

2.2 Macroergonomic Perspective

Macroergonomics is a "top-down approach to system design based on a sociotechnical system perspective." (Hendrick, 1986) It is an approach concerned with "the optimization of organizational and work system design through consideration of relevant personnel, technological, and environmental variables and their interactions." (Brown, Hendrick, Imada, and Kleiner, 1997) Therefore, by considering the appropriate sociotechnical variables in the analysis, design, implementation, evaluation, and control process, work systems can be optimized. In this study, a tutoring system was the domain of interest. Tutoring loosely fits into the definition of an organization. Students and tutors met for a short period of time for the purpose of helping the student to understand a problem. The students and the tutors along with their personal individual beliefs and backgrounds are part of the personnel subsystem. The process and media the tutors and students use to communication is part of the technological subsystem. The subsystems exist in an environment containing political and economic forces that influence the tutoring system.

According to sociotechnical systems theory, a system is comprised of personnel, technological, and job design subsystems which exist under the influence of the environment (Hendrick, 1986). Sociotechnical systems theory prescribes jointly optimizing the personnel subsystem and technological subsystem as a function of the demands of the environment as shown in Figure 2.1 (Pasmore, Francis, Haldeman, and Shani, 1982). Based on their joint design, a prescription for the job design can be formed.

Sociotechnical theory views the system as an open system. Therefore, any changes made to the subsystems will affect the overall system. These subsystems must be considered jointly to optimize the overall system. For example, once organizations design their technological subsystem it remains relatively fixed (Hendrick, 1986). Organizations expect the personnel subsystem to adapt to the technological subsystem which will result in sub-optimization of the overall system (Hendrick, 1986).

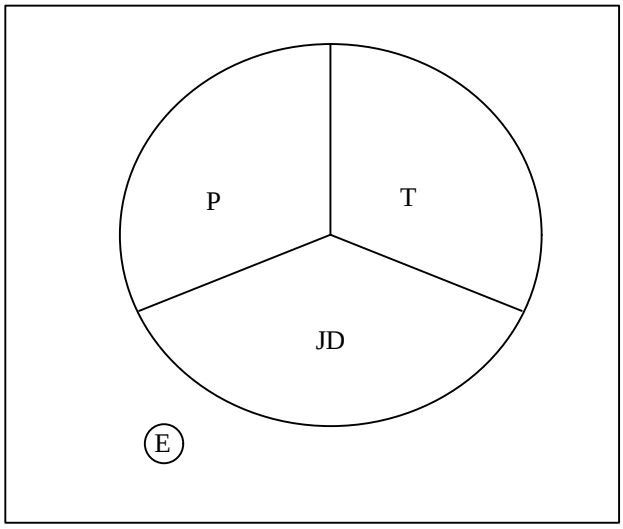

Figure 2.1 How the subsystems fit into the environment (adapted from Eason, 1988)

2.2.1 The Environment

Organizations are open systems. Therefore, the understanding the environment in which an organization functions was important to understanding the tutoring system. The students' environment was comprised of the university environment, the specific college (e.g., College of Engineering) environment, and their peer environment (e.g., residence halls, social organizations). Engineering students within a university were relatively isolated. Instructors, peers, and family influenced them. Students have been managing themselves within this environment for many years. The environment within engineering tends to be conservative.

Introducing the communication technology to the environment added additional complexity to the system. Communication technology enabled students to communicate through their computers with almost anyone, for example, other students, faculty, tutors, etc. This environment can be referred to as a virtual environment (Grenier and Metes, 1995). Students had to learn to adapt to a computer-mediated environment as well as an engineering philosophy and university atmosphere.

Virtual environments are flexible and adaptable and people rely on cyberspace and other technical links for communication (Barnatt, 1995). However, many situations may occur where students will make first impressions via virtual technology. Phone mail presents a good analogy for this situation. Many people will hang up as opposed to leaving a message on an answering machine with a long message especially if it is an unprofessional message (K. Ware, personal communication, August, 1993). Therefore, students must learn to have short concise messages by the time they look for internships, cooperative jobs, or jobs upon graduation. But, this is a mode of functioning that many students must learn. Similarly, students might adapt their personal conversation style when communicating virtually.

2.2.2 The Personnel Subsystem

The personnel subsystem of an organization includes the people in an organization and their relationships to one another (Pasmore et al., 1982). Hendrick supported two methods of defining people within the personnel subsystem: the degree of professionalism and psycho-characteristics (Hendrick, 1986). The degree of professionalism is related to the level of education and training. Therefore most freshman

students have a low degree of professionalism. The degree of professionalism increases as they continue in their education and move into jobs.

Psychosocial characteristics are a function of cognitive complexity and cultural factors. Cognitive complexity refers to the way people conceptualize and process information and is measured by a concrete-abstract scale (Hendrick, 1984). The four levels of the concrete-abstract scale include conventional thinking, general negativism, the world is people, and autonomous. Most people fall into specific categories based on their age. However, people can move up or down the scale based on their exposure to diversity and active exposure to diversity. Within the university, many students are exposed to new cultures, new ways of thinking, new technologies, and new ideas. Because of this exposure, many students fall into the general negativism category on the concrete-abstract scale – this is a transitional stage. The culture that a student is raised in will influence their values and beliefs as they enter college. Pai (1984) said, "the culture of a society consists of the standards and control mechanisms with which its members assign meanings, values and significance to things, events and behaviors." (p. 7)

Communication skills are important for students to develop. When students join the work force, they are expected to have well-developed written and verbal skills (Katz, 1993). Nonverbal communication helps to provide the context for spoken communication (Tan, 1992). Meaning can be lost in a conversation with some students if the communication is not done in person. This has implications for a student's preference for a type of communication technology to aid tutoring.

In communication, feedback between speakers and listeners is important in order to determine if the message has been conveyed (O'Conaill et al., 1993). Absences of feedback might delay the progress of the conversation. In text based communication, feedback must be explicitly stated. For example, the listener must write to the speaker that he does or does not understand what the speaker just wrote. In video teleconferencing, lags in video frames might create delays in conversation which can negatively influence satisfaction (Kies, 1997; Kies, Williges, and Rosson, 1997). Or it might cause one person to speak for longer periods of time than they would have if the conversation were face-to-face (O'Conaill et al., 1993).

Students need current and appropriate feedback on their learning process (Briggs, Ramesh, Romano, and Latimer, 1994). People give and seek feedback to evaluate their performance (Ashford and Cummings, 1983). In tutoring situations, students seeking feedback from tutors was important for evaluating their understanding (McKendree, 1990). In addition, students must give tutors feedback on how well they understood the information the tutor conveyed. However, asking for feedback and giving feedback can be a threatening task (Ashford et al. 1983). The idea of receiving negative feedback can be especially threatening (Ashford et al., 1983). Ang and Cummings (1994) found feedback was sought at greater rates using computer-mediated communication as opposed to face-to-face communications. They found this trend occurred even when the feedback was negative. Feedback can be given in the form of cues. A cue contains both instruction and direction (Lysakowski and Walberg, 1982). Cues are used to reinforce behavior (Lysakowski et al., 1982). Using symbolic cues might be a non-threatening method for students to give and receive feedback with tutors.

2.2.3 The Technological Subsystem

Skills, knowledge, tasks, processes, and procedures in addition to technology make up the technological subsystem (Pasmore et al., 1982). The purpose of the technological subsystem is to convert input into outputs (Pasmore, 1988).

2.2.3.1 Computer-Mediated Communication. Several researchers defined computer-mediated communication (CMC) to be a synchronous or asynchronous electronic mail and conferencing where senders encode text to be sent and received through the use of a computer (Walther, 1992; Hiltz, Turoff, and Johnson, 1981; Olaniran, 1995; Straus, 1997). In this study, computer-mediated communication was extended to include video teleconferencing because the conferencing system had a text channel in addition to video and audio channels and a computer was used support all channels. Several theories have been used to explain the differences in communication media.

Social presence theory is the ability of a medium to allow users to feel collocated (Short, Williams, and Christie, 1976). This theory was used to develop hypotheses regarding telecommunications. Short (1976) indicated that social presence is a quality of the medium. Some of the characteristics the media differ by include sociability, warmth, personalness, and sensitivity (Fulk, Steinfield, Schmitz, and Power, 1987). Face-to-face communication is generally seen as having the greatest social presence. Proponents of social presence theory contend that the medium required to communicate about a given task is a function of the media's level of social presence and the interpersonal involvement required by the task (Fulk et al., 1987).

Sproull and Kiesler (1986) contended that computer-mediated communication reduced the social context cues in communication. Social context cues included geographic location, organizational position, and situational variables that influenced the perceptions between communicators. Sproull and Kiesler differentiated between static and dynamic cues. Static cues came from appearances and the physical surroundings of the people communicating. Dynamic cues came from "nonverbal behavior which changes over the course of an interaction" (Sproull et al., 1986; p. 1495). According to Sproull and Kiesler, electronic mail minimized static cues and removes dynamic cues. From their study, they found evidence supporting the difference between electronic mail and face-to-face communication was a reduction in social context cues and an increase in uninhibited behavior.

Media Richness Theory is based on the concept that different communication media transmit different degrees of information (Daft and Lengel, 1984, 1986; Walther, 1992). Communication media are differentiated in terms of immediacy of feedback, communication channels and cues, nonverbal cues, source, and language. Email and chatroom were both lean communication media because the nonverbal cues were eliminated and the immediacy of feedback was slow. While collocated communication was the richest medium, video teleconferencing was also rich because of the capacity for verbal and nonverbal channels (Walther, 1992; Kies, 1997; Kies, et al., 1997). The media richness theory suggested that the equivocality of the task should match the communication medium. The more equivocal the information the richer the media should be (Daft et al., 1984).

The social presence, lack of social context cues, and media richness theories are similar in that the reduction of cues is considered a critical difference between communication media, especially between collocated and CMC (Daft et al., 1984, 1986; Walther, 1992). Several researchers have used these theories to study CMC and video teleconferencing with mixed results (Walther, 1992; Kinney and Dennis, 1994). However, social presence and media richness theories provided a common language from which CMC research could be discussed.

"One of the prime motivations for using [computer-mediated communication] is to take advantage of the flexibility it can support for both learners and tutors." (Steeples, Unsworth, Bryson, Goodyear, Riding, Fowell, Levy, and Duffy, 1996) Communication technology can be used to bring people together to share knowledge and information even if they are separated by a distance. Grenier and Metes (1995) referred to this idea as virtual learning. Virtual learning is a "designed, collaborative, continuous learning

process," where students build a knowledge base (Grenier and Metes, 1995; p. 245). The concept of virtual learning originated in distance learning and education. Although distance learning has several definitions, within the United States distance learning is often thought of as "education that takes place when the learner and instructor are at separate locations (Zeller, 1995; p. 123)." Through new and innovative technology, distance learning is enhanced to the point where students can organize together to create a virtual learning system.

The Group Support Systems (GSS) literature provided theory behind bringing groups of people together with technology. McGrath and Hollingshead (1994) defined three drivers of technical support: improving task performance, overcoming space and time constraints, and increasing information access. Each of these drivers applies directly to the tutoring concept. GSS provides the link for students to collaborate with others -- both inside and outside the university community.

Group Support Systems can be broken into two categories: Group Decision Support Systems (GDSS) and Group Communication Support Systems (GCSS). The main purposed of GDSS is to structure groups' decision process (Pinsonneault and Kraemer, 1990). Examples of GDSS include automated nominal group technique, decision conference, and handling the aggregation of group member's preferences (Pinsonneault et al., 1990). Group Communication Support Systems primarily act as "information aids" (Pinsonneault et al., 1990). The purpose of GCSS is to reduce barriers of communication (Pinsonneault et al., 1990). Teleconferencing, email, and electronic boardrooms are some examples of GCSS (McGrath et al., 1994).

Some measures have been developed for determining the effects of using GSS. Task focus has been measured by the number of task oriented remarks, number of alternative proposals considered, and the number of group members actively involved in the task at different points in time (McLeod, 1992; Siegel, Dubrovsky, Kiesler, and McGuire, 1986). Participation equity, task quality, and satisfaction are additional measures of the effect of GSS (McLeod, 1992; Easton, Vogel, and Nunamaker, 1989; Ellis and Jarvenpaa, 1989; Olaniran, 1996, 1995). Another measure is time on task. Verbal communication was found to be three times as fast as communicating through typing (Hiltz, Johnson, and Turoff, 1986; Siegel et al., 1986). Therefore, groups using text-based computer communication "will exchange less communication than [face-to-face] groups in the same amount of elapsed time." (Hiltz et al., 1986; p. 227)

Many studies have shown GSS groups generally performed better than face-to-face groups (Easton et al., 1989; Ellis et al., 1989; Smith et al., 1989; Gallupe and DeSanctis, 1988; Turnoff et al., 1982). For example, Pinsonneault (1990) found that GSS groups looked at more alternatives or they looked at the alternatives in greater depth than non-GSS groups. In a meta-analysis of thirteen of GSS studies, McLeod (1992) found some general trends in GSS. McLeod included studies from 1980 to 1990 that were experiments and had quantitative data. The analysis showed GSS increased task focus, task quality, and participation equality. However, decisions took longer times, and there was lower satisfaction. McLeod pointed out the results on user satisfaction were not statistically significant. In addition, McLeod found evidence that the results found in GDSS studies did not differ from GCSS studies (1992). However, not all researchers agreed with this finding (Pinsonneault et al., 1990). Smith and Vanecek (1989) found that computer-mediated communication with a time lag frustrated the users. However, this disadvantage was off set by the advantage that people did not have to be present at the same time to carry out the communication.

Text-based communication technology allows people to communicate in different places at either different times or at the same time. Researchers studied the differences between people meeting using text based computer-mediated methods as opposed to face-to-face. Weeks and Chapanis (1976) found the time

to develop a solution took significantly longer in text-based communication than in face-to-face communication. They also found groups using text-based communication were more focused on the task than groups in face-to-face or video telecommunications. Dubrovsky, Kiesler, and Sethna (1991) found the effect of social status inequalities between group members was reduced. The reason was that the people communicating were not identified by age, race, appearance, or gender (Dubrovsky et al., 1991). Dubrovsky (1991) referred to this effect as the "equalization phenomenon." (p. 125) Hiltz (1986) found that more communication occurred in face-to-face meetings than in text-based communication with a time lag. However, the quality of the task was not diminished. In addition, their study found no significant differences in the quality of the task for face-to-face and text-based computer communication with a time lag. Other studies that supported this finding did not find a significant difference in task quality between collocated meetings and computer-mediated communication (Burke and Chidambaram, 1994; Smith et al., 1989).

Video teleconferencing allows people to communicate real time but in different places. In addition to being able to see and hear one another, people have access to a text-based communication channel. "These technologies are premised on the hypothesis that the more closely they mimic face-to-face communication, the more effective the communication that will take place." (O'Conaill et al., 1993; p. 391) Some of the disadvantages of video teleconferencing systems included low frame rate transmission and poor quality video (O'Conaill et al., 1993). For tasks involving information exchange and question asking video teleconferencing appeared to be effective (Hiltz et al., 1986). Ochsman and Chapanis (1974) found voice links significantly reduced the amount of time required to complete problem solving tasks. However, studies have found video links did not have a significant impact on the time required to complete problem solving tasks (Ochsman et al., 1974; Weeks et al., 1976). Weeks and Chapanis (1976) did not find significant differences in the time it took teams to develop a solution in video telecommunication and face-to-face communication.

2.2.3.2 Tutoring. Tutoring was generally supported by the literature as having a positive effect on students' academic performance (Franklin, Griffin and Perry, 1994; House and Wohlt, 1990; Gahan-Rech, Stephens and Buchalter, 1989; Harrar and Ender, 1987; McKellar, 1986; Burton and Elliot, 1986). Not all research found tutoring had a positive effect on academic performance (Cohen, Kulik, and Kulik, 1982). However, the number of studies that found tutoring did not significantly improve academic performance was small (Cohen et al., 1982).

There were several types of tutoring covered in the literature. "Peer tutoring is defined as a one-to-one teaching process in which the tutor is of the same general academic status as the tutee." (Cohen, 1986; p. 175) Other researchers believed peer tutoring included the characteristic that the student had the chance to be both the tutor and tutored (Fantuzzo, Riggio, Connelly, and Dimeff, 1989; Magolda and Rogers, 1987). Others defined tutoring to simply be focused teaching to a few individuals (MacDonald, 1991). In this study, tutoring encompassed parts of some of these definitions. This study used people relatively close in academic status to the students being tutored from peer tutoring. In addition, the tutoring process was a guiding process more than a teaching process.

Different tutoring studies have used several different kinds of dependent variables to measure the effectiveness of tutoring. Several studies were developed for a specific class. In some of these studies, the measure was the grade for each test (Franklin et al., 1994; Cohen et al., 1982). In other cases the measure is a final grade in the class (Yunker and Horras, 1991). Other researchers structured a more general approach to tutoring; tutoring was given for all classes taken over a semester or year. Then the measures included cumulative grade point averages and/or credit hours earned (House et al., 1990). Other measures

included students' attitude toward the subject matter being tutored, the student's self-concept, and student satisfaction (Cohen et al., 1982; Fantuzzo et al., 1989).

Hartman (1990) wrote, "the purpose of tutoring is to facilitate academic gain and develop self-directed or independent learners." (p.2) With this view of tutoring, tutors must focus on the cognitive process more than the subject matter. Cognitive processes are the methods by which students organize, store, and retrieve information (Sternberg, 1985). The tutor's role then would be to direct learning instead of leading it (McKeachie, 1994). Three main knowledge acquisition skills are differentiating relevant from irrelevant information, comparing what you already know to what you need to learn, and selectively combining relevant and combining apparently disparate old and new information into a new and meaningful whole (Sternberg, 1985). Problem solving is one domain that applies to building both cognitive processes and subject matter.

2.2.3.3 Problem Solving. In the mid-1950's, problem based learning was developed within the medical field as an educational approach (Savery and Duffy, 1995). More recently, this approach has been used in other fields including engineering (Meier, Hovde, and Meier, 1996). The benefit of problem based learning is students become engaged in a problem solving behavior that they are expected to exhibit in their professional practice (Savery et al., 1995).

Many models exist for problem based learning (Savery and Duffy, 1995; Meier, and Hovde, 1996; Polya, 1957). Polya's model lends itself to the tutoring process. The four phases in his problem solving model include understand the problem, develop a plan, carry out the plan (solve the problem), and review the complete solution (Polya, 1957).

Understand the Problem: First, the students must familiarize themselves with what the problem is. Understanding the problem is demonstrated through restating the problem in their own words and if applicable using diagrams to visualize the problem.

Develop a Plan: Students outline the steps required to develop a solution to the problem. Included in the outline are the equations and constructions required to arrive at the unknown. In this stage, if the students are not progressing, the tutor's role is to give "unobtrusive help" (Polya, 1957; pp. 8-9). Asking questions or providing analogies of related problems is one way for the tutor to guide the students. This stage is most helpful when the connection between the information provided in the question and the unknown is not directly apparent (Meier, Sherry, Hovde, 1996). Therefore, rote number crunching would not be appropriate as a problem solving task.

Carry Out the Plan: Students fill in the steps they planned out in the previous phase. The tutor's role in this phase is to help the students stick to their plan. Alternatives suggested should be noted but kept for discussion in the next phase.

Review the Solution: In this phase, students reflect on their process and check their solution. Polya (1957) recommended using dimensional analysis, e.g., feet, pounds, etc., as an additional check on the solution. They should also determine if other methods could have been used to arrive at the same conclusion. Then look to see if they could have arrived at different solutions. They also review with the tutor to determine how well they solved the problem. The students can iterate back through the process if they are not satisfied with their solution.

The problem solving approach to learning is usually facilitated by someone with broad experience in the problem area (Savery et al., 1995). In this research, the tutor was the facilitator who guided the problem solving process.

2.2.4 Job Design

The job design of tutoring can be described by the level of "complexity" (Hendrick, 1986). He defined complexity as "the degree of differentiation and integration that exist within an organization (Hendrick, 1986; p. 468)." Spatial differentiation describes the geographical dispersion among the individuals in a group. Therefore, by nature, virtual environments have high spatial differentiation. When spatial differentiation is high, integration or coordination must also be high, which the technology aids. Through the use of technology, students solved problems with a tutor's help. The technology helped the student and tutors overcome spatial barriers that would have previously prevented them from meeting.

Chapter 3 Methodology

The purpose of this chapter was to describe how this study was conducted.

3.1 Overview

The following were the research questions in this study:

- Research Question 1: How will computer-mediated communication technology affect the students' performance?
- Research Question 2: How will access to a feedback cue affect the students' performance?
- Research Question 3: How will the interaction between feedback cue level and technology level affect students' performance?
- Research Question 4: How will computer-mediated communication affect the process time for tutoring?
- Research Question 5: How will access to a feedback cue affect the process time for tutoring?
- Research Question 6: How will the interaction between feedback cue level and technology level affect students' process time?
- Research Question 7: How will the computer-mediated communication affect how students perceive the tutoring process? Which level of technology will the students prefer?
- Research Question 8: How will feedback cues affect how students perceive the tutoring process?
- Research Question 9: How will the interaction between feedback cue and technology level affect satisfaction?
- Research Question 10: What is the optimal configuration for tutoring? Does this configuration depend on phase?
- Research Question 11: How will the tutor perceive his participation in the system? In which levels of technology and feedback cue will the tutor have the highest level of satisfaction?

3.1.1 Experimental Design

Sixty-four laboratory trials were conducted in this study. A laboratory experiment was chosen to control the environment. An attempt was made to isolate the independent variables, phase, technology, and feedback cue, and the interactions between the independent variables. The research design was a 2x4x4 factorial within subject's design as shown in Table 3.1. The main factors were phase, technology, and feedback cue. The tutoring approach used in this experiment was a four-phased problem solving method. The first phase was for the subject to understand the problem. The second phase was for the subject to plan the approach to the problem. In the third phase, the subject solved the problem according to the plan developed in Phase 2. And in the fourth phase, the tutor led the subject back through the first three phases to determine if the problem was solved correctly. All subjects used the four-phased problem solving method in each trial.

The feedback cue was a nonverbal mechanism that subjects had access to which provided the tutor with information on the subject's level of understanding. Subjects had access to three power strips that

represented a high, medium, and low level of understanding. The symbol the subject showed to the tutor reflected the student's level of understanding at all times during the tutoring process. The two levels of the feedback cue were no access to a feedback cue and access to a feedback cue.

Technology referred to the four levels of communication media which were collocated, email, chatroom, and video teleconferencing. This continuum was chosen for two reasons. First the literature supported using the variations of email and video teleconferencing as typical text-based and audio-visual lined communication. However, each level of technology more closely simulated reality. In email, communication was text-based and asynchronous. With a chatroom, communication was still text-based, but communication was synchronous in that the text instantly appeared on the computer screen. Also, chatrooms allowed multiple people to communicate at one time. Video teleconferencing was synchronous and there were audio, video, and textual communication channels. Video teleconferencing was most similar to collocated communication, where students could see the tutor, talk to the tutor, and write down information and share it with the tutor.

Table 3.1 Research design matrix

			Technology			
			Collocated	Email	Chatroom	Video Teleconferencing
			T_1	T_2	T_3	T_4
Phase	Feedback Cue					
Phase 1	No Cue	C_1				
P_1	Cue	C_2				
Phase 2	No Cue	C_1				
P_2	Cue	C_2				
Phase 3	No Cue	C_1				
P_3	Cue	C_2				
Phase 4	No Cue	C_1				
P_4	Cue	C_2				

3.1.2 Task Assignment

Each participant was given eight math problems to solve. All participants received the math problems in the same order. The participant was asked to solve the math problem under a tutor's guidance using the four-phased problem solving approach. The participants' mathematics instructor determined the math problems. Each problem covered concepts taught in class prior to the day the participants received math problem. The math instructor assigned each problem for the participants to apply the concepts taught in class. In class, participants typically practiced concepts by substituting numbers into an equation and solving the equation. Word problems were not given in class for the participants to practice concepts. In addition, several math problems brought two concepts together in order to solve the problem; again this was not done in class. The mathematics instructor attempted to assign problems that were equally difficult.

3.1.3 Participant Assignment to Experimental Condition

In this study, participants solved math problems in eight different experimental conditions. Therefore, the order participants were assigned to conditions could confound the results. In order to have a true counter-balanced experimental design, there would have to have been 40,320 (or 8!) participants. There were eight experimental conditions and for eight conditions there were 40,320 ways in which the conditions have been arranged (or ordered). For every possible order of treatment conditions to have

occurred, a different subject was needed for each possible order or 40,320 subjects were needed. However, using 40,320 subjects was not feasible. A Latin square can be used to balance for order effects and reduce the number of subjects needed to learn about the main effects (independent variables) and interactions (Winer, Brown, and Michels, 1991). As this number of subjects (40,320) was not feasible, a modified version of the Latin square was used to assign subjects to experimental conditions (Winer et al., 1991).

The change-over design, which is a form of the Latin square, was used to assign subjects to the experimental conditions (Hinkelmann and Kempthorne, 1994). A characteristic of the change-over design is each experimental condition precedes and follows every other experimental condition (Hinkelmann et al., 1994). For this research eight people were needed to be subjects because there were eight experimental conditions.

Table 3.2 shows the assignment of participants to conditions. The y-axis represents the subject number and the x-axis represents the math problem number. The matrix is coded: C_1V_1 = collocated without a feedback cue; C_1V_2 = email without a feedback cue, C_1V_3 = chatroom without a feedback cue, C_1V_4 = video teleconferencing without a feedback cue, C_2V_1 = collocated with a feedback cue, C_2V_2 = email with a feedback cue, C_2V_3 = chatroom with a feedback cue, C_2V_4 = video teleconferencing with a feedback cue. Since this was a within subject design, all subjects participated in each condition; therefore, there were eight subjects per condition.

Four additional people were needed for this research. In order to simulate a real chatroom environment, more than two participants needed to be on-line (for example, more than just the tutor and subject). Therefore, in each chatroom, two additional people, referred to as control people, were always on-line for tutoring assistance. The control people worked the same math problem as the subject. The same two people were always paired together for each chatroom; however, the two pairs were balanced in terms of access to feedback cue conditions and subjects. Each subject worked once with each control pair. Each control pair participated in four conditions with access to feedback cues and four conditions without feedback cues.

Table 3.2 Assignment of subjects to experimental conditions

	Math Problem Number							
Subject	1	2	3	4	5	6	7	8
1	C_1T_1	C_2T_4	C_1T_2	C_2T_3	C_1T_3	C_2T_2	C_1T_4	C_2T_1
2	C_1T_2	C_1T_1	C_1T_3	C_2T_4	C_1T_4	C_2T_3	C_2T_1	C_2T_2
3	C_1T_3	C_1T_2	C_1T_4	C_1T_1	C_2T_1	C_2T_4	C_2T_2	C_2T_3
4	C_1T_4	C_1T_3	C_2T_1	C_1T_2	C_2T_2	C_1T_1	C_2T_3	C_2T_4
5	C_2T_1	C_1T_4	C_2T_2	C_1T_3	C_2T_3	C_1T_2	C_2T_4	C_1T_1
6	C_2T_2	C_2T_1	C_2T_3	C_1T_4	C_2T_4	C_1T_3	C_1T_1	C_1T_2
7	C_2T_3	C_2T_2	C_2T_4	C_2T_1	C_1T_1	C_1T_4	C_1T_2	C_1T_3
8	C_2T_4	C_2T_3	C_1T_1	C_2T_2	C_1T_2	C_2T_1	C_1T_3	C_1T_4

Where C_iT_j = the i^{th} level of feedback cue and the j^{th} level of technology.

3.2 Subjects

The subjects were sampled from the Black pre-engineering freshman students who attended the Academic Summer Program Introducing Resources for Engineers (ASPIRE '97) at Virginia Tech. The program ran from Sunday, June 29, 1997 until Saturday, August 2, 1997. All subjects were engineering freshmen at Virginia Tech as of Fall Semester, 1997. All subjects were taking a pre-calculus class. The

math problems in this research were designed to follow the concepts covered on the pre-calculus class syllabus. Students were not given course credit for their participation in this research.

Each subject was at least 18 years of age. Due to this limitation, of the 29 participants in ASPIRE '97, only 15 were eligible to participate in this research. These ages were comparable to freshman students. The gender of the subjects was not restricted but was documented. House and Wohlt found that males who participated in tutoring earned higher grades than males whom did not participate in tutoring; this effect was not found among females (1990). In an earlier study, House found that "students earned better grades when working with same-sex tutors than when working with opposite-sex tutors." (1989; p. 195)

The concepts covered in the pre-calculus class were new material for some of the participants and review for others. Because this was typical for many students in their freshman year, the students' mathematical and computer ability were not restricted. The incentive for participation was 1) to gain help on pre-calculus topics, 2) have exposure to different types of computer-mediated communication, and 3) to practice problem solving skills necessary for engineering students.

The subjects also participated in a computer course. By the start of this experiment, each subject was taught how to use email. When subjects were in a computer-mediated experimental condition (for example, not in collocated communication), a five-minute training hand out and exercise was given to the students on how to use feedback cues and virtual technology. Refer to Appendix A.1 for the handouts and exercises. In the exercise, students were led through the steps required for communication to occur. The training time was not included in the one hour allowed for each trial.

The schedule of activities for all ASPIRE '97 participants is given in Table 3.3. Students also were not available to participate in this study on weekends and after 10:00 p.m. on weekdays.

The researcher ran trials on Monday, Tuesday, and Thursday. Because two workstations were required for the subjects' work (video teleconferencing and chatroom software were on two different machines), the technology levels were fixed for specific times. From the pilot testing, collocated communication appeared to have the fastest process time. Therefore, after the subject finished the collocated condition, the video teleconference workstation and the chatroom workstation could be switched without disrupting the timing of the trials. On Thursdays, to reduce the number of workstation changes, the chatroom was left for the last two trials of the day. The times and corresponding technology level used for Mondays and Tuesdays are shown in Table 3.4. The ASPIRE participants were divided into computer class A and computer class B. On Mondays, subjects that were in computer class B participated in trials. On Tuesdays, subjects that were in computer class A participated in the trials. A single task was given on Mondays and Tuesdays. On Thursdays, subjects were scheduled to avoid conflict with their computer class. The times and corresponding technology level used for Thursdays are shown in Table 3.5.

Table 3.3 Daily schedule of activities for the ASPIRE '97 participants

	Monday	Tuesday	Wednesday	Thursday	Friday
8:00 - 9: 30 a.m.	Chemistry Lecture	Chemistry Lecture	Chemistry Lecture	Chemistry Lab	Chemistry Lecture
9:45 -11:15 a.m.	Math Lecture	Math Lecture	Math Lab		Math Lecture
11:30 a.m. - 12:30 p.m.	Seminar	Seminar		Seminar	Academic Analysis
12:30 p.m. - 1:30 p.m.	Lunch	Lunch	Lunch	Lunch	Lunch
1:45 - 3:00 p.m.	Academic Analysis[1]		Academic Analysis	Academic Analysis	Problem Solving
3:00 -5:00 p.m.	Computers A[2]	Computers B[2]	Computers A	Computers B	
7:00 p.m.			Orientation		

[1]Each student participated in one twenty-minute academic analysis session once per week.
[2]Due to space considerations, students were divided into two groups for the computer sessions. The groups were formed based on computer ability.

Table 3.4 Times of trials on Mondays and Tuesdays

Time	Level of Technology
3:20 - 4:20 p.m.	video teleconferencing
4:25 - 5:25 p.m.	collocated
5:30 - 6:30 p.m.	email
6:35 - 7:35 p.m.	chatroom

Table 3.5 Times of trials on Thursdays

Time	Level of Technology
11:30 a.m. - 12:30 p.m.	video teleconferencing
12:35 - 1:35 p.m.	collocated
1:40 - 2:40 p.m.	email
2:45 - 3:45 p.m.	video teleconferencing
3:50 - 4:50 p.m.	collocated
4:55 - 5:55 p.m.	email
6:00 - 7:00 p.m.	chatroom
7:05 - 8:05 p.m.	chatroom

The first set of trials were conducted on Thursday of the first week of the ASPIRE '97 program. The second, third, and fourth weeks of class, the trials were conducted on Monday/Tuesday and Thursday. The last week of class, trials were conducted on Monday/Tuesday. According to the program Director's preferences, trials were not conducted after 8:30 p.m.

Because the students who were available to participate in this research were Black students, a literature review was conducted to determine if there might be learning and/or communication differences that might influence the outcomes in this research. Black students in predominantly white institutions have more complex issues than the traditional student within the university environment (Nora, Cabrera, Hagedorn, and Pascarella, 1996; Watson and Kuh, 1996; DeSousa and Kuh, 1996; Love, 1993). Black students have been facing this issue since the mid-1960's (Renner, 1993). Tidwell and Berry (1993) reported "[m]any of these young men and women brought with them obstructions associated with their minority status, which usually has meant an experience of poor schools,…, and a history of social

experiences that are not always rewarded on campus." (p. 467) Love (1993) reported "[c]ommonly, they [Black students] find themselves ignored in classroom discussions, shut out of the campus social life, and ignored or harassed by the police." (p.28) Historically academic performance has been characterized as being lower for black students than for white students (NSF 1994, 1996). "Black students in PWIs [predominately white institutions] graduate about one third less often than their white counterparts." (Love, 1993; p. 27)

In addition the personnel subsystem for a Black student might be different from their white counterparts. Typically, Black students turn to their families and friends for moral support in learning to adjust to their new environments (Hughes, 1987). Many researchers point to a need for an increase in positive relationships between faculty and students although this has been historically difficult (Dinka, Mazzella and Pilant, 1980; Hughes, 1987; Astin, 1977). Communication is another social dimension that is somewhat different for Black students than white students. Black students tend to rely on body language to communicate (Shade, 1989).

The process by which black students learn is one component of the technological subsystem. Research says "a cooperative academic attitude [is] prevalent among the African American students (Jagers, 1992; p. 537)." In addition, "they prefer active involvement rather than passive (Shade, 1989; p. 27)." Another difference is many students of African dissent think holistically as opposed to decomposing a problem and then synthesizing the pieces for the final answer (Locke, 1992). Cooperation and holistic thinking contradict traditional institutional teaching methods.

Some studies have addressed the issue of race in tutoring. Through survey research, Akah (1990), from Ohio State University, found that 80% of their black students did not care what the race of the tutor was. However, 5% of their black students felt strongly that they preferred a black tutor. House and Wohlt (1990) found that black students who participated in their study had lower grades that the rest of the population both with and without tutoring. They suggest this outcome might be explained by a study by Nettles, Thoeny, and Gosman (1986). Nettles reported that Black students seem to have poorly developed study skills upon their arrival at college. This suggests that tutoring programs should attempt to help students improve their study skills and habits.

3.3 Materials and Equipment

All subjects were provided with the following materials: a math problem, the math book used in the math class, a pencil, eraser, calculator, paper, ruler, and a set of instructions. All subjects in computer-mediated communication modes (for example, V_2 or higher) had access to a personal computer. In email, EudoraLight™, an electronic mail software package developed by QUALCOMM Incorporated™, was the software package used to communicate. EudoraLight™ allowed for intermittent (asynchronous) text-based communication. Subjects who were in a chatroom used Microsoft® NetMeeting™, a free-ware software package that allowed continuous real-time text communication. For video teleconferencing, subjects had a video camera, audio speakers, a microphone, and enhanced CUSeeMe™ for Windows, version 2.1. Originally Cornell University developed CUSeeMe™ as freeware. The software was later licensed to White Pine© Software who developed the version used in this research. The five workstations used in this research were identical. Each consisted of the same furniture, computer monitor and case, keyboard, mouse, mouse pad, video camera, and speakers.

Subjects with access to feedback cues had three power strips with color-coded labels representing a high understanding (green), medium understanding (blue), and low understanding (red). In the chatroom

condition, when the subject had access to the feedback cue, the two control people also had access to their own feedback cue. The power strips were connected to a set of lamps with the same color codes and labels that were located at the tutor's workstation. The tutor adjusted his tutoring to the level of the light display. For example, when a red light was showing the tutor asked the subject questions to find out what was not understood or he would explain a concept in more detail.

Each trial was videotaped. Three video camera recorders (VCR) were used. One VCR captured the subject's and the subject's workspace, one captured the tutor and the tutor's workspace, and one captured the information on the subject's computer monitor when the condition was computer-mediated communication. A high-eight video recorder was used to videotape the subject. A flexi-cam was used to videotape the tutor. In addition, two flexi-cams were used to capture audible information from both the subject and tutor. Three monitors were used to verify the video cameras and sound were working properly.

3.3.1 Mathematics Problems

Eight mathematics problems were chosen with expert help (the ASPIRE '97 pre-calculus instructor). All math problems and solutions can be found in Appendix A.2 in the order that the subjects received them. Each problem was designed to last approximately forty-five minutes. Each subject received the eight problems in the same sequence. However, each subject worked only one problem in each experimental condition. These problems were designed for students to develop their problem solving skills. Each problem contained a problem statement and, when necessary, a figure. The tutor acted as the problem expert. However, because of the problem solving method used for tutoring, the student could, if they chose, work with little or no help from the tutor until the last phase, which is when the tutor reviewed the problem with the student.

Five of the eight problems covered separate concepts. The first question was a review question that covered basic math and algebra skills required for problem solving. The second problem covered concepts related to the equation of a straight line. The third, fourth, and fifth questions covered geometry and algebra skills. Each problem had a different geometric figure and required slightly different algebra skills. Trigonometry was the topic for the sixth question. The seventh question covered functions and inverse functions. Natural logarithms and exponential functions were the topics for the eighth question.

3.3.2 Supplemental Questionnaires

The Tuesday before subjects began to participate in trials, a background questionnaire was administered. This questionnaire can be found in Appendix A.3. The questionnaire collected demographic information.

To supplement the data collected in the laboratory experiment, questionnaires were administered to each subject immediately after each phase. An overall questionnaire was administered when the trial was complete. The questionnaires are located in Appendix A.3. The questionnaires were identical except for those administered during the condition with access to a feedback cue. Each questionnaire collected information on satisfaction, ease of use, efficiency, and effectiveness of the experimental condition and feedback (when applicable). There was also a space for subjects to write any comments they had. In the overall questionnaire, the subjects were specifically asked to comment on the overall tutoring process, the technology level, and the feedback cue (if applicable). The tutor was asked about his opinion of the subject's performance and how satisfied he was with the experimental condition.

Questionnaires are appropriate when attitudes are being investigated (Martin, 1996). Only one variable was considered in each question. A five-point Likert-type scale was used with anchors of "strongly agree" with a value of one to "strongly disagree" with a value of five. The midpoint was anchored by "neither agree nor disagree" and had a value of three. Because the spacing of the anchors was equal, parametric statistical methods were used to analyze the results.

Once the subjects completed all the trials, they were asked to rank order all of the experimental conditions. Subjects rank ordered their preferences five times, once for each phase and once for the overall process. In addition, subjects described their opinions of each experimental condition. The rank order questionnaire can be found in Appendix A.3.

3.3.3 Tutor Script

To help minimize the differences between each trial the tutor followed a script. A sample script can be found in Appendix A.4.

3.4 Facilities

All experimental conditions in this study were conducted in the Usability Methods Research Laboratory located in McBryde Hall. This laboratory had four rooms containing the equipment required in this study. For the collocated condition, Room 3 was used. For the computer-mediated conditions, the tutor was located in Room 1 and the subject was located in Room 3. Room 3 had a table for collocated conditions and two workstations for computer-mediated conditions. One workstation had chatroom and email capabilities and the other workstation had video teleconferencing and email capabilities. Due to technical difficulties, the chatroom and video teleconference software could not be loaded on the same machine. The workstations were interchanged depending on the computer-mediated condition. Room 1 had four workstations. The tutor only used one workstation which had the capabilities for all computer-mediated conditions. Room 2 had a single workstation with chatroom capabilities for one of the control people. In addition, Room 2 had two one-way mirrors for observation in Rooms 1 and 3 and videotaping capabilities. The hallway connecting the three rooms was used for the other control person's workstation for the chatroom.

3.5 Experimental Design

3.5.1 Justification of Experimental Methodology

Each type of research methodology has inherent advantages and disadvantages. Martin (1996) discussed these strengths and weaknesses for research methods that typically use human subjects. Table 3.6 is a summary of Martin's discussion. Other considerations in the methodology are internal and external validity. External validity is the generalizability of the method (Martin, 1996). And internal validity refers to the dependent variable changing as a result of the influence of the independent variable (Martin, 1996; Leedy, 1993). Internal validity is threatened by non-random assignment of subjects to experimental conditions.

Questionnaires can be used to gain supplemental information from subjects. Questionnaires applied before and after laboratory research can be used for appraisal of task performance, adequacy of

technology, effect of a condition on performance, and to evaluate performance (Williges, 1996). A questionnaire(s) coupled with laboratory research is a good method to study a large number of people.

Table 3.6 Summary of advantages and disadvantages of human subject research designs (Adapted from Martin, 1996)

Design	Variable Control	Causal Inferences	External Validity
Lab Experiment	High	High	Low
Field Experiment	Medium to Low	Medium	High
Questionnaires (Survey)	Medium	Low	High
Case Study	Low	Low	Medium

The questionnaire questions in this research that asked for opinion used a Likert-type scale (Williges, 1996). The characteristics of this scale include a statement with a five-point rating scale, a horizontal and continuous scale with five labeled anchors, and equivalent intervals between anchors. The anchors were "strongly agree" (weight equal to one), "agree" (weight equal to two), "neither agree nor disagree" (weight equal to three), "disagree" (weight equal to four), and "strongly disagree" (weight equal to five).

A goal of this research was to establish causality. A strength of laboratory research is the ability to establish causality. External validity is typically low in laboratory research. One reason is students are typically used as subjects to represent the population as a whole. In this research, the domain of interest was students. This suggests a better ability to generalize to the Black student population in engineering at predominately white universities. However, generalizing to the student population as a whole was questionable. Control in this research was desirable in order to determine causation.

3.5.2 Pilot Testing

A pilot test was completed for this research. Because the tutor to be used in the experiment was not in Blacksburg until the ASPIRE '97 program began, another person with tutoring experience acted as the tutor. Originally, two subjects were to be used for group tutoring. Therefore the pilot testing began using group tutoring. However, in early June after several experimental conditions had been tested, several people that met the age criterion who said they would attend the ASPIRE '97 program did not attend for various reasons. Therefore, the remaining experimental conditions were tested using a single subject. The other subject became a control person for the chatroom. The subjects were two students that completed their freshman year courses during spring semester, 1997. The additional control person used for the chatroom was a person who was not related to the university community. The subjects and control people signed an institutional review board release form.

Each math problem was pilot tested in one experimental condition due to time constraints. All eight experimental conditions were tested. The purposes of the pilot test were as follows:

1. Find out if the subjects understood the instructions given by the tutor and the researcher. The tutor read through the script several times before the pilot testing began and made several changes to the script. Then during the trials, the subjects were instructed to interrupt the tutor any time they did not understand the instructions. Several changes were made to the script during the pilot testing.

2. Check that the tutor and subjects understood the questionnaires and that there were no errors, for example, typographical errors. Several minor changes were made to the questionnaires based on the subjects' comments.
3. Check the time constraint chosen for this study (1 hour). Originally, the training exercise was to be included in the hour time limit. However, based on the amount of time taken in the pilot, the training exercise was not included in the one-hour time limit. The subject(s) solved all of the problems within the 1 hour time limit with the exception of the seventh problem (functions and inverse functions) which was worked in the chatroom condition. After interviewing the subject, it was determined one reason for the time problem was due to a software issue. The chatroom screen cut off text longer than approximately two lines of characters if there were no spaces between the characters. Therefore, the tutor missed important information the subject typed into the chatroom. Another time issue was caused by the original problem which required two methods of verifying the inverse function. After discussing the problem with the mathematics instructor, only one method of verifying the inverse function was required.
4. Ensure the training materials for the computer-mediated conditions and the feedback cue were understandable. In addition, determine if the training exercises were sufficient (Appendix A.1). Both of the subjects were familiar with email. Only one of the subjects was familiar with a chatroom and neither subject was familiar with video teleconferencing. The chatroom control person was computer illiterate. Based on the subjects' feedback, several clarifications and simplifications were made in the directions.
5. Tested software and hardware. During the pilot testing, it became obvious the email software had to be set to check itself every minute (this was as fastest setting) because subjects would not check their mail. A technical issue was found with the chatroom: long sequences of characters without a space would be cut off when it appeared on the chat screen. Both problems were highlighted in the training instructions. Another issue that arose was the researcher had to state very clearly that the subjects could not change the configuration on the computer monitor. Both subjects in the pilot testing were curious about the chatroom and video teleconferencing displays and accidentally closed the software programs.

3.6 Procedure

The following steps were required prior to conducting the research:

1. Institutional Review Board (IRB) approval was applied for and obtained. Because this research involved human subjects, IRB approval was required. The approved IRB form is located in Appendix A.5. The first part of the document provided to IRB indicated this research was to involve group tutoring. However, the number of subjects eligible to participate in the tutoring process was not large enough for the experimental design. The experimental design called for 16 subjects; only 15 ASPIRE participants met the minimum age requirement. Therefore, one-on-one tutoring was agreed upon for the method of tutoring. This change was reflected in the subject portion of the IRB consent form.
2. The Usability Methods Research Laboratory (104 McBryde) was scheduled for the month of July and first week of August.
3. The tutor was trained on how to use the technology. The tutor practiced reading from the script (Appendix A.4) and the tutor reviewed the math problem solutions with the researcher.

4. During the Sunday night ASPIRE '97 introduction meeting, the researcher solicited help for this research. The program's Director strongly encouraged everyone to sign up to participate in this study. Then a sign up sheet was passed around; 100% of the participants signed the sheet.

5. Students under 18 years of age were immediately removed from the pool of potential subjects. The remaining students were randomly selected to participate. The random number command in EXCEL was used to generate a number by each person's name. The students with the eight lowest numbers were chosen to be subjects. Then the students with the next two lowest numbers were chosen to be one pair of control persons for the chatroom and the students with the next two lowest numbers were chosen to be the other pair of control persons. Students were assigned experimental conditions based on the change-over design (Table 3.2). Then schedules were created according to the subject's computer class because it was the only potential time conflict. Four of the subjects were in computer class A and four subjects were in computer class B. Each pair of control persons was also equally divided between the computer classes.

6. The researcher met with the students selected on the Wednesday prior to the day the research began. The informed consent forms were distributed for their signatures and collected. The background questionnaire (Appendix A.3) was administered and collected. A schedule for each subject and control person was distributed and checked for conflicts. The researcher encouraged questions throughout this meeting. Copies of the signed informed consent forms were distributed the following day.

7. Each day, one hour prior to the first trial of the day, the researcher ran through the laboratory set up checklist, Appendix A.6. During the run through on the first day of trials, the researcher found the subject's computer would not support the chatroom software. Therefore, another workstation was brought into the room that did support this software. Unfortunately, the workstation that supported the chatroom software would not support the video teleconferencing software. Both workstations did support the email software. Therefore, the workstations were interchanged based on the communication conditions. The first trial began five minutes late. This problem did not affect the subjects because the subjects did not take the full hour during the collocated conditions. Therefore, the workstations were switched either immediately after the video teleconference condition if there was time or after the collocated condition was complete. The email and chatroom windows were maximized to fill the entire computer monitor. The video teleconferencing window was setup as shown in Figure 3.1.

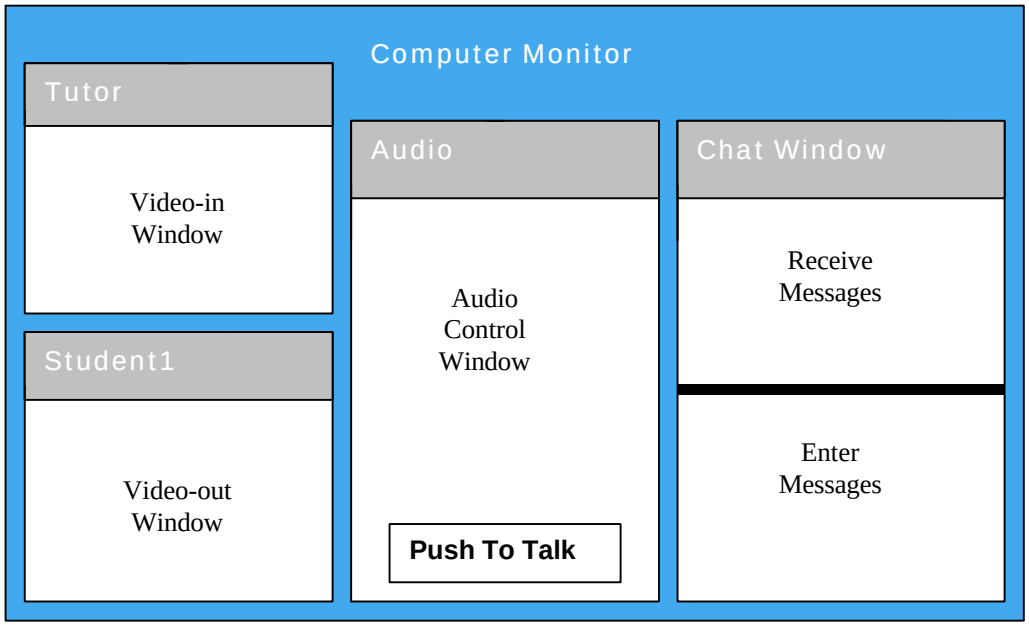

Figure 3.1 Schematic of the computer monitor as it appeared for video teleconferencing

8. Once subjects arrived at the research facility for their first experimental condition, they were given a copy of their signed informed consent form that included contact information.
9. Subjects were given handouts including general instructions, laminated technology directions (technology and/or feedback cue) with an exercise on how to use the communication technology and/or feedback cue for all conditions. Subjects in the collocated condition without feedback cues received the general instructions. The subjects were told to read through the handouts, do the exercise, and ask if they needed help or had questions. These handouts are located in Appendix A.1.
10. While the subjects were becoming familiar with the technology, the researcher turned on the video recorder located in Room 2. Videotapes were used to collect data that could not be collected in real time, for example, the number of times the feedback cue was used.
11. Once the subject had completed the exercise, the subject was told the researcher would be available at any time to respond to questions about the experiment, but any other question should be directed to the tutor.
12. Finally, the subject was given the math problem and a worksheet for the first phase (Appendix A.2). The subject would tell the tutor he or she was ready to begin and the tutor began to read the introduction section of the script (Appendix A.4).

The rest of the procedures are sub-divided based on the problem solving phase.

3.6.1 Understand the Problem

The Understand the Problem Phase started when the tutor began to read the Phase 1 instructions to the subject. In the collocated and video teleconferencing communication conditions, the timing began when the tutor started to read the instructions. In the text-based conditions, time began once the tutor sent the first set of instructions. The phase ended when the subject restated the problem in his or her own words

and was satisfied with the restatement. In the collocated and video teleconferencing communication conditions, this occurred once the subject verbally told the tutor he or she had a problem statement. And in the text-based conditions, this occurred when the tutor received the statements.

The purpose of this stage was to encourage the subjects to read through the problem carefully and become familiar with what the problem was asking. Typically, if the subject did not understand something, he or she asked the tutor for help or indicated confusion by using the feedback cue. The products of understanding the problem were a problem statement and possibly a diagram. The subject also filled out a Phase 1 questionnaire (Appendix A.3). The questionnaire was designed to capture the subject's confidence in his or her own understanding of the problem, the ability to understand the tutor, and the satisfaction with the experimental condition. For subjects involved with feedback cues, additional questions were asked regarding the satisfaction with using the feedback cue. Once the subject finished the questionnaire, the researcher collected the questionnaire and gave the subject a worksheet for Phase 2, Plan the Approach.

3.6.2 Plan the Approach

The Plan the Approach Phase started when the tutor began to read to the subject from the script for collocated communication and video teleconferencing or once the tutor sent the next set of directions in the text-based conditions. This phase ended when the subject had a detailed plan for solving the problem. In this phase, the subject needed to determine what information was needed to solve the problem, what was unknown in the problem, what equations were needed to solve the problem, and finally, the steps to take to solve the problem. The output from this phase was a list of knowns, unknowns, equations, outline of the steps they would take, and the Phase 2 questionnaire (Appendix A.3). This questionnaire was identical to the Phase 1 questionnaire except it was designed to capture information about the confidence in the plan as opposed to confidence in the understanding of the problem. Once the subject completed the questionnaire, the researcher gave the subject the Phase 3 worksheet.

3.6.3 Implement Plan (Solve the Problem)

The Implement the Plan Phase started when the tutor began to read to the subject from the script in the collocated and the video teleconferencing communication or once the tutor sent the next set of instructions in the text-based communication. This phase ended when the subject had a solution to the problem. In this phase, the subject should have followed the plan developed in Phase 2. However, the subject was not required to adhere to the plan. The output from this stage was the problem solution including all mathematical manipulations, and the Phase 3 questionnaire (Appendix A.3). Again this questionnaire was identical to the previous two questionnaires except it was designed to capture information about the confidence in the solution. Once the subject finished the questionnaire, the researcher collected the pencil and questionnaire. Then, the researcher gave the subject the Phase 4 worksheet and a green pen. The researcher instructed the subject to use the green pen from this point forward for any changes, or corrections. The researchers also asked the subject not to cross out any previous work.

3.6.4 Review the Solution

The Review the Solution Phase started when the tutor began to read or had sent the directions for Phase 4. This phase ended once the tutor finished taking the subject back through the previous three phases and discussed alternative approaches to the problem. The tutor and subject worked through mistakes, both conceptual and mathematical, and reworked alternative methods. The output from this phase was potentially the problem reworked correctly, the problem worked using an alternative method, and the Phase

4 questionnaire (Appendix A.3). This questionnaire was identical to the questionnaires in Phases 1 through 3, but information was collected on the subjects' confidence with their results in this phase.

After the Phase 4 questionnaire was collected, the researcher administered the overall tutoring process questionnaire (Appendix A.3) to collect information about the students' satisfaction with the process overall and satisfaction with the technology and feedback (when applicable). Again, this questionnaire was similar to the phase questionnaires.

3.7 Data Collection

The data collected in this study is shown in Table 3.7.

Table 3.7 Data list

Pre-Experiment Data Element	Variable Type	Collector	Logged
Math SAT	analyze subject differences	researcher	researcher log
Class Rank	analyze subject differences	researcher	researcher log
Highest Math Class	analyze subject differences	researcher	background survey
Experience with Technology	analyze subject differences	researcher	background survey
Experience with Tutoring	analyze subject differences	researcher	background survey
Understand the Problem (UP)			
UP process time	outcome	tutor	tutor log
accuracy of problem restatement	outcome	expert	problem log[2]
number of cue uses	process	researcher	researcher log[2]
number of cue increases	process	researcher	researcher log[2]
number of cue decreases	process	researcher	researcher log[2]
ease of use of the technology	outcome	subject	UP survey
ease of use of the feedback cue	outcome	subject	UP survey
technology effectiveness	outcome	subject	UP survey
feedback cue effectiveness	outcome	subject	UP survey
technology efficiency	outcome	subject	UP survey
feedback efficiency	outcome	subject	UP survey
technology satisfaction	outcome	subject	UP survey
feedback cue satisfaction	outcome	subject	UP survey
overall satisfaction for phase	outcome	subject	UP survey
tutor completely answered questions	process	subject	UP survey
understanding of problem statement	process	subject	UP survey
interaction conflict with tutor	process	subject	UP survey
confidence with problem restatement	process	subject	UP survey
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey

[2]Collected on videotape

Table 3.7 Data list (continued)

Plan the Approach (PA) Data Element	Variable Type	Collector	Logged
PA process time	outcome	tutor	tutor log
accuracy of plan	outcome	expert	problem log[2]
number of cue uses	process	researcher	researcher log[2]
number of cue increases	process	researcher	researcher log[2]
number of cue decreases	process	researcher	researcher log[2]
ease of use of the technology	outcome	subject	PA survey
ease of use of the feedback cue	outcome	subject	PA survey
technology effectiveness	outcome	subject	PA survey
feedback cue effectiveness	outcome	subject	PA survey
technology efficiency	outcome	subject	PA survey
feedback efficiency	outcome	subject	PA survey
technology satisfaction	outcome	subject	PA survey
feedback cue satisfaction	outcome	subject	PA survey
overall satisfaction for phase	outcome	subject	PA survey
tutor completely answered questions	process	subject	PA survey
understanding of plan	process	subject	PA survey
interaction conflict with tutor	process	subject	PA survey
confidence with plan	process	subject	PA survey
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey
Implement Plan (IP)			
IP process time	outcome	tutor	tutor log
accuracy of solution	outcome	expert	problem log[2]
number of cue uses	process	researcher	researcher log[2]
number of cue increases	process	researcher	researcher log[2]
number of cue decreases	process	researcher	researcher log[2]
ease of use of the technology	outcome	subject	IP survey
ease of use of the feedback cue	outcome	subject	IP survey
technology effectiveness	outcome	subject	IP survey
feedback cue effectiveness	outcome	subject	IP survey
technology efficiency	outcome	subject	IP survey
feedback efficiency	outcome	subject	IP survey
technology satisfaction	outcome	subject	IP survey
feedback cue satisfaction	outcome	subject	IP survey
overall satisfaction for phase	outcome	subject	IP survey
tutor completely answered questions	process	subject	IP survey
understanding of solution	process	subject	IP survey
interaction conflict with tutor	process	subject	IP survey
confidence with solution	process	subject	IP survey
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey

[2]Collected on videotape

Table 3.7 Data list (continued)

Review Solution (RS) Data Element	Variable Type	Collector	Logged
RS Process Time	outcome	tutor	tutor log
accuracy of review	outcome	expert	problem log[2]
number of cue uses	process	researcher	researcher log[2]
number of cue increases	process	researcher	researcher log[2]
number of cue decreases	process	researcher	researcher log[2]
ease of use of the technology	outcome	subject	RS survey
ease of use of the feedback cue	outcome	subject	RS survey
technology effectiveness	outcome	subject	RS survey
feedback cue effectiveness	outcome	subject	RS survey
technology efficiency	outcome	subject	RS survey
feedback efficiency	outcome	subject	RS survey
technology satisfaction	outcome	subject	RS survey
feedback cue satisfaction	outcome	subject	RS survey
overall satisfaction for phase	outcome	subject	RS survey
tutor completely answered questions	process	subject	RS survey
understanding of review	process	subject	RS survey
interaction conflict with tutor	process	subject	RS survey
confidence with solution review	process	subject	RS survey
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey
Overall (O)			
total task time	outcome	researcher	researcher log
overall accuracy	outcome	expert	problem log
ease of use of technology	outcome	subject	O survey
feedback ease of use	outcome	subject	O survey
technology effectiveness	outcome	subject	O survey
feedback effectiveness	outcome	subject	O survey
technology efficiency	outcome	subject	O survey
feedback efficiency	outcome	subject	O survey
technology satisfaction	outcome	subject	O survey
satisfaction with overall process	outcome	subject	O survey
tutor completely answered questions	process	subject	O survey
understanding concepts	process	subject	O survey
interaction conflict with tutor	process	subject	O survey
confidence with solution review	process	subject	O survey
number of cue uses	process	researcher	researcher log[2]
number of cue increases	process	researcher	researcher log[2]
number of cue decreases	process	researcher	researcher log[2]
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey

[2]Collected on videotape

Table 3.7 Data list (continued)

Tutor (T) Data Element	Variable Type	Collector	Logged
perception of subjects ability to solve problem	process	tutor	T survey
completely answered subject's questions	process	tutor	T survey
ease of use of technology	outcome	tutor	T survey
feedback ease of use	outcome	tutor	T survey
technology effectiveness	outcome	tutor	T survey
feedback effectiveness	outcome	tutor	T survey
technology efficiency	outcome	tutor	T survey
feedback efficiency	outcome	tutor	T survey
technology satisfaction	outcome	tutor	T survey
feedback satisfaction	outcome	tutor	T survey
satisfaction with overall process	outcome	tutor	T survey
experimental condition efficiency ranks	process	subject	rank order survey
experimental condition effectiveness ranks	process	subject	rank order survey
experimental condition satisfaction ranks	outcome	subject	rank order survey
experimental condition comfort ranks	process	subject	rank order survey
experimental condition ease of use ranks	process	subject	rank order survey

[2]Collected on videotape

The expert referred to in Table 3.7 was the mathematics instructor for the ASPIRE '97 pre-calculus class. The expert reviewed the steps the subjects took in the process to assess the task accuracy. These variables included accuracy of the problem restatement (and diagram if drawn), accuracy of the plan, accuracy of the solution, and accuracy of the problem review. Appendix A.2 contains the criteria and associated points which the expert used to assess the task outputs (note, these are in red ink on the problem solution). The tutor recorded the process times (or speed) to complete each phase. A questionnaire was used to determine the students and tutor's satisfaction with the technology and the feedback cues in addition to effectiveness, efficiency and ease of use of the technology and feedback cue. The tutor completed a questionnaire after each trial to collect data about the efficiency, effectiveness, ease of use, and satisfaction with the feedback cue and technology. In addition, after the tutor and subjects completed all of their trials, they rank ordered all of the experimental conditions for satisfaction, ease of use, efficiency, effectiveness, and comfort. The ranked order questionnaires were completed for all phases and the overall tutoring process. The researcher reviewed the videotape for all trials to count the number of times the feedback cue was used and the number of increases and decreases in the feedback cue. In addition, the researcher used the videotapes of the trial to record the subject's answers and corrections in purple on the worksheet when the subject had verbally answered the questions as opposed to writing down the answers.

Chapter 4 Results

4.1 Analysis Methods for Research Questions

Data was collected and analyzed to answer the following research questions:

- Research Question 1: How will computer-mediated communication technology affect the students' performance?
- Research Question 2: How will access to a feedback cue affect the students' performance?
- Research Question 3: How will the interaction between feedback cue level and technology level affect students' performance?
- Research Question 4: How will computer-mediated communication affect the process time for tutoring?
- Research Question 5: How will access to a feedback cue affect the process time for tutoring?
- Research Question 6: How will the interaction between feedback cue level and technology level affect students' process time?
- Research Question 7: How will the computer-mediated communication affect how students perceive the tutoring process? Which level of technology will the students prefer?
- Research Question 8: How will feedback cues affect how students perceive the tutoring process?
- Research Question 9: How will the interaction between feedback cue level and technology level affect satisfaction?
- Research Question 10: What is the optimal configuration for tutoring? Does this configuration depend on phase?
- Research Question 11: How will the tutor perceive his participation in the system? Which levels of technology and feedback cue will have the highest level of satisfaction for the tutor?

This experiment was a three-factor within subject design with two levels of one factor and four levels of the other two factors. Subjects were assigned to conditions according to a change-over design which is a form of a Latin square to control for ordering effects. Unless otherwise noted, all statistical tests in this research were conducted using MINITAB.

For parametric analyses, a 0.05 decision level was used to determine statistical significance. For the nonparametric test known as Friedman's test, the decision level was 0.01. The decision level indicated that when the probably of the null hypothesis occurring was less than 5 times out of 100 (or in Friedman's test, 1 time in 100) then the null hypothesis was rejected (Martin, 1996). The type I error, α, was 0.05 for the parametric tests and 0.01 for Friedman's test. The type I error was the probability of rejecting the null hypothesis when the null hypothesis was true (Winer, Brown, and Michels, 1991).

Multivariate analysis of variance (MANOVA) was used prior to univariate analysis of variance. In order for an effect or interaction to be significant, the mean difference needs to be larger in the multivariate compared to the univariate ANOVA, which may reduce the possibility of type I error. Two relationships were tested with MANOVA: 1) effect of accuracy, perceived accuracy, perceived understanding, and tutor's perception of subject understanding and 2) effect of satisfaction, effectiveness,

efficiency, and ease of use on the main effects and the interactions between the main effects (Olaniran, 1995 and 1996).

The analysis that was used to determine statistical significance of the dependent variables, accuracy and process time, and supplemental questionnaire data were two-way and three-way analysis of variance (ANOVA) with eight observations per cell. The analysis of the overall tutoring process was conducted using a two-way ANOVA to determine statistical significance. The appropriate model for the two-way design was of the form

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha_i\beta_j + \alpha_i\gamma_k + \beta_j\gamma_k + \alpha_i\beta_j\gamma_k + \varepsilon_l$$

The ANOVA summary tables had the form shown in Table 4.1. The first column showed the source of the variation. The second column contained the degrees of freedom for each source. The third column was for the sum of squares, the fourth column was for the mean sum of squares, and the fifth column was for the F statistic.

Table 4.1 Form of the two-way ANOVA table for dependent variables

Source	df	SS	MS	F
Between				
S	n-1	SS_S		
Within				
T	t-1	SS_T	MS_T	MS_T/MS_{TxS}
TxS	(t-1)(n-1)	SS_{TxS}	MS_{TxS}	
C	c-1	SS_C	MS_C	MS_C/MS_{CxS}
CxS	(c-1)(n-1)	SS_{CxS}	MS_{CxS}	
TxC	(t-1)(c-1)	SS_{TxC}	MS_{TxC}	MS_{TxC}/MS_{TxCxS}
TxCxS	(t-1)(c-1)(n-1)	SS_{TxCxS}	MS_{TxCxS}	
Total	tcn-1	SS_{Total}		

The analysis of the data for all phases was conducted using a three-way ANOVA. The model for the three-way design had the form

$$Y_{ijklm} = \mu + \alpha_i + \beta_j + \delta_k + \gamma_l + \alpha\beta_{ij} + \alpha\delta_{ik} + \alpha\gamma_{il} + \beta\delta_{jk} + \beta\gamma_{jl} + \delta\gamma_{kl} + \alpha\beta\delta_{ijk} + \alpha\beta\gamma_{ijl} + \alpha\delta\gamma_{ikl} + \beta\delta\gamma_{jkl} + \varepsilon_{m(ijkl)}$$

The ANOVA table had the form shown in Table 4.2. Again, the first column contained the source of the variation. The second column showed the degrees of freedom for each source. In the third column had the sum of squares for error. The fourth column contained the mean sum of squares for error, and the fifth column had the F statistic.

Table 4.2 Form of the three-way ANOVA table for dependent variables

Source	df	SS	MS	F
Between				
S	n-1	SS_S		
Within				
P	p-1	SS_P	MS_P	MS_P/MS_{PxS}
PxS	(p-1)(n-1)	SS_{PxS}	MS_{PxS}	
T	t-1	SS_T	MS_T	MS_T/MS_{TxS}
TxS	(t-1)(n-1)	SS_{TxS}	MS_{TxS}	
C	c-1	SS_C	MS_C	MS_C/MS_{CxS}
CxS	(c-1)(n-1)	SS_{CxS}	MS_{CxS}	
PxT	(p-1)(t-1)	SS_{PxT}	MS_{PxT}	MS_{PxT}/MS_{PxTxS}
PxTxS	(p-1)(t-1)(n-1)	SS_{PxTxS}	MS_{PxTxS}	
PxC	(p-1)(c-1)	SS_{PxC}	MS_{PxC}	MS_{PxC}/MS_{PxCxS}
PxCxS	(p-1)(c-1)(n-1)	SS_{PxCxS}	MS_{PxCxS}	
TxC	(t-1)(c-1)	SS_{TxC}	MS_{TxC}	MS_{TxC}/MS_{TxCxS}
TxCxS	(t-1)(c-1)(n-1)	SS_{TxCxS}	MS_{TxCxS}	
PxTxC	(p-1)(t-1)(c-1)	SS_{PxTxC}	MS_{PxTxC}	$MS_{PxTxC}/MS_{PxTxCxS}$
PxTxCxS	(p-1)(t-1)(c-1)(n-1)	$SS_{PxTxCxS}$	$MS_{PxTxCxS}$	
Total	tcn-1	SS_{Total}		

The variables that were tested using an ANOVA included accuracy, process time, and questionnaire subjective response results. The reason the questionnaire results were tested with a parametric procedure was that a Likert-type scale was used. Therefore, the anchors were equally spaced and had descriptive and numerical descriptions. The accuracy and process time contained missing data points. The data were incomplete for one of two reasons: 1) during Phase 3, subjects asked to tutor to continue to the next Phase 4 without obtaining a solution in Phase 3 or 2) subjects ran out of time in Phase 4. The SPSS software package was used to conduct ANOVA with missing data and the associated multiple comparison tests. In the ANOVA with missing data, the sum of squares calculation was tested with a "Type IV" test, which "distributes the contrast being made among the parameters in the effect to all higher-level effects equitably." (SPSS, 1997) The degrees of freedom for the error term in the ANOVA table was reduced by the number of missing data points.

Post hoc analysis was conducted if there were significant main effects and interactions. The least significant difference (LSD) test was used to perform pairwise multiple comparisons between the levels of the significant effect. This was the least conservative of all of the pair comparison tests because there was no correction for an inflated α.

Analysis of variance should not be performed on variables with a nominal or ordinal scale of measurement. Nominal means that the data are frequency counts of classifications and ordinal means the data can be ordered, for example, one data point is greater than or less than another data point (Siegel and Castellan, 1988). To determine the experimental condition in which the subjects had the highest level of satisfaction, the subjects were asked to rank all conditions from one to eight.

To analyze the main effects of the variable that were ranked, Friedman's test was used. The subjects ranked eight treatment conditions, four levels of technology with access to a feedback cue and four levels of technology without access to a feedback cue. For the main effect of technology, the ranks for the two occurrences for each technology level were summed together and then re-ordered. For the main effect

of feedback cue the four occurrences of feedback cue were summed together and re-ordered. In the situation of ties, mid-ranks were used (if the tie was two levels had ranks of 2, the ranks of the second and third location would be used for both levels resulting in a rank of 2.5 for both levels).

For significant effects, pair-wise multiple comparisons were performed as a post hoc analysis. The pair-wise comparisons were tested at an overall error rate of 0.6 (experimentwise error rate of 0.05). This decision level was not as stringent as the recommended individual level of 0.01 because this study was exploratory in nature. The medians of the two treatment groups being compared were considered significantly different if:

$$\left|R_i - R_j\right| \geq Z_{a^*}\sqrt{\frac{nk(k+1)}{6}}$$

Where R_i and R_j were the sum of the ranks for the i^{th} and j^{th} respectively, n was the number of blocks, k was the number of treatments, and Z_{α^*} was a point on the normal curve based on the experimentwise error rate.

One of the drawbacks of Friedman's test is that the interaction cannot be tested. Therefore, analysis of variance was used to determine the statistical significance of the interaction. Least significant differences were performed as a post hoc analysis of significant interactions.

The following sections contain the results of this experiment. The data in all phases was analyzed in addition to the data for the overall tutoring process.

4.2 Performance

Appendix A.7 contains the accuracy data collected in this research. In the situation when subjects did not complete a task, the data point has an asterisk (*) beside it. The analysis for accuracy was conducted both with and without the incomplete trial data. The argument to include all data was that in a timed assignment, for example, a test, the assignment would be evaluated for the work presented regardless of running out of time or not being able to determine a solution to a problem. The argument for excluding the data was that in the controlled laboratory environment, including the accuracy for unfinished work might confound the results. Confounding might occur because the research cannot predict if the subject would be able to determine the correct solution given more time.

In the supplemental questionnaires (Appendix A.3), subjects responded to two questions related to accuracy: 1) the subjects' perceived accuracy and 2) the subjects' perceived understanding. The responses to both questions can be found in Appendix A.8. In addition the tutor responded to one question related to accuracy. He gave his perception of the subject's understanding of the problem after each trial was complete. The tutor's responses are located in Appendix A.9

For the analysis by phase, a multivariate analysis of variance was performed on accuracy and the perceptions of accuracy and understanding. From this analysis, phase and the interaction between phase and technology level were significant as shown in Table 4.3. For the overall tutoring process, a multivariate analysis of variance was conducted on overall accuracy, the subject's perceptions of overall accuracy and overall understanding, and the tutor's perception of the subjects' understanding. From the analysis on the overall process, technology was significant as shown in Table 4.4. For the complete

MANOVA results refer to Appendix A.10. Univariate ANOVAs were performed for each dependent variable.

Table 4.3 Multivariate analysis of variance to test the affect of accuracy and perceptions of accuracy and understanding on the main effects and interactions

	All Data		Excluding Incomplete Data	
	F	P	F	P
Technology	1.399	0.212	1.320	0.249
Feedback	4.207	0.078	4.005	0.085
Phase	3.827	0.001*	5.452	<0.001*
Technology x Feedback	0.747	0.664	1.155	0.343
Phase x Feedback	1.044	0.419	1.676	0.118
Phase x Technology	1.864	0.009*	1.803	0.013*
Phase x Feedback x Technology	1.250	0.196	0.953	0.536

*$p < 0.05$

Table 4.4 Multivariate analysis of variance to test the affect of overall accuracy and perceptions of overall accuracy and overall understanding, and tutor's perception of understanding on main effects and the interaction

	All Data		Excluding Incomplete Data	
	F	P	F	P
Technology	2.332	0.018*	2.514	0.011*
Feedback	1.368	0.384	2.998	0.156
Technology x Feedback	0.619	0.816	2.038	0.069

*$p < 0.05$

4.2.1 Accuracy

Task accuracy was one measure of performance. The mathematics instructor developed a point system for specific outcomes for each phase of the task. Then for each phase, she rated each subject's task on a scale from one to ten. The overall accuracy was calculated by summing the accuracy score in each phase. The ANOVA table for the analysis by phase is shown in Table 4.5 and the ANOVA table for the overall process analysis is shown in Table A.11 (Appendix A.11).

Feedback was not significant for either the analysis by phase or the analysis for the overall process. Although the differences were not significant, mean accuracy and mean overall accuracy was higher in experimental conditions with feedback cues (by phase: mean = 7.609, sd = 2.498; overall: mean = 30.437, sd = 6.725) compared to conditions without feedback cues (by phase: mean = 7.227, sd = 2.698; overall: mean = 28.906, sd = 7.450).

While the differences between mean accuracy in each technology level were not significant, the mean accuracy was the highest in collocated communication (mean = 8.109, sd = 2.378), followed by email (mean = 7.484, sd = 2.749), chatroom (mean = 7.406, sd = 2.321), and video teleconferencing (mean = 6.672, sd = 2.783). Although the differences were not significant, the mean overall accuracy scores followed the same trend as the mean accuracy for each phase (collocated: mean = 32.438, sd = 6.429; email: mean = 29.938, sd = 7.629; chatroom: mean = 29.625, sd = 5.315; and video teleconferencing: mean = 26.688, sd = 8.072).

Table 4.5 ANOVA summary table for accuracy in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	125.496	17.928		
Within					
P	3	108.355	36.118	8.517	0.001*
PxS	21	89.051	4.241		
C	1	9.379	9.379	5.43	0.053
CxS	7	12.090	1.727		
T	3	66.512	22.171	1.398	0.271
TxS	21	333.145	15.864		
PxC	3	0.199	0.066	0.032	0.992
PxCxS	21	42.957	2.046		
PxT	9	73.348	8.150	1.868	0.073
PxTxS	63	274.871	4.363		
CxT	3	24.043	8.014	0.767	0.525
CxTxS	21	219.363	10.446		
PxCxT	9	22.066	2.452	0.475	0.886
PxCxTxS	63	325.402	5.165		
Total	255	1726.277			

* $p < 0.01$

Phase significantly affected accuracy. The mean accuracy for each phase is shown in Figure 4.1. To determine which phases were significantly different, multiple comparison tests were performed; the results are given in Table 4.6. The mean accuracy in Phase 3 (mean = 6.500, sd = 2.867) was significantly lower than the mean accuracy in either Phase 1 (mean = 7.844, sd = 2.945) or Phase 4 (mean = 8.188, sd = 1.918). Furthermore, the mean accuracy in Phase 2 (mean = 7.141, sd = 2.260) was significantly lower than the mean accuracy in Phase 4.

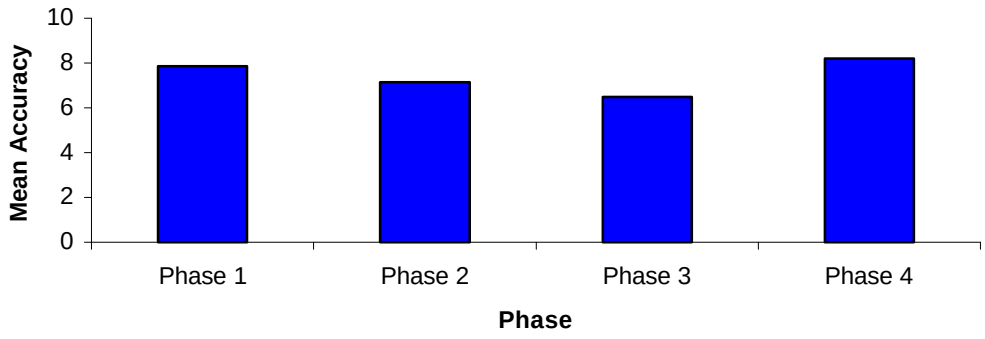

Figure 4.1 Comparison of the mean accuracy for each phase

Table 4.6 Multiple comparisons of mean accuracy between phase levels

			Phase 2	Phase 1	Phase 4
		mean	7.141	7.844	8.188
	mean				
Phase 3	6.500		0.641	1.344*	1.688*
Phase 2	7.141			0.703	1.047*
Phase 1	7.844				0.344

*p < 0.05

The data for accuracy excluding incomplete trial data was highly correlated with accuracy (Pearson product moment: by phase = 0.998 and overall = 0.961). Results for the analysis of accuracy excluding incomplete trial data by phase and for the overall process were similar to the discussion of accuracy. Refer to Appendix A.12 for the ANOVA tables and multiple comparisons of significant effects.

4.2.2 Perceived Accuracy

Tables 4.7 and 4.8 contain the ANOVA results for the analysis of perceived accuracy analyzed by phase and for the overall process, respectively. Although feedback cue was not significant in either analysis, there was a slight trend in the data. The mean perceived accuracy in conditions with a feedback cue (by phase: mean = 3.938, sd = 0.957 and overall: mean = 4.438, sd = 1.014) was slightly higher than the mean perceived accuracy in conditions without a feedback cue (by phase: mean = 3.727, sd = 1.055 and overall mean = 4.063, sd = 1.268).

Table 4.7 ANOVA summary table for the accuracy response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	33.312	4.759		
Within					
P	3	17.687	5.896	3.195	0.044*
PxS	21	38.750	1.845		
C	1	1.891	1.891	1.878	0.213
CxS	7	7.047	1.007		
T	3	7.156	2.385	2.440	0.093
TxS	21	20.531	0.978		
PxC	3	0.422	0.141	0.271	0.845
PxCxS	21	10.891	0.519		
PxT	9	9.531	1.059	1.667	0.116
PxTxS	63	40.031	0.635		
CxT	9	2.391	0.797	0.594	0.626
CxTxS	21	28.172	1.342		
PxCxT	9	8.922	0.991	2.210	0.033*
PxCxTxS	63	28.266	0.449		
Total	255	255.000			

* p < 0.05

Table 4.8 ANOVA summary table for the overall accuracy response

Source	df	SS	MS	F	p-value
Between					
S	7	15.750	2.250		
Within					
C	1	2.250	2.250	2.625	0.149
CxS	7	6.000	0.857		
T	3	15.875	5.292	3.783	0.026*
TxS	21	29.375	1.399		
CxT	9	29.375	1.042	1.882	0.164
CxTxS	21	11.625	0.554		
Total	63	84.000			

*$p < 0.05$

From the analysis by phase, technology did not significantly affect perceived accuracy. While the differences were not significant, the mean perceived accuracy was highest in collocated communication (mean = 4.063, sd = 0.871) followed by video teleconferencing (mean = 3.859, sd = 3.859), the chatroom (mean = 3.703, sd = 1.178), and email (mean = 3.625, sd = 0.934).

Technology significantly affected the subjects' mean overall perceived accuracy. Figure 4.2 shows the mean accuracy response for each technology level. Multiple comparisons were conducted to determine which technology levels were significantly different (Table 4.9). Both text-based modes (email: mean = 3.500, sd = 1.317; and chatroom: mean = 4.188, sd = 1.328) had significantly lower mean overall accuracy responses than collocated communication (mean = 4.875, sd = 0.342). In addition, the mean overall accuracy response was significantly lower when subject used email than when they used either the chatroom or video teleconferencing (mean = 4.437, sd = 0.964).

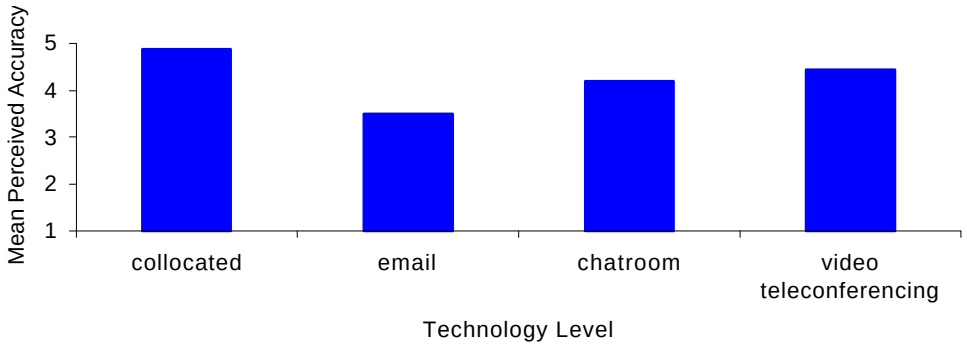

Figure 4.2 Comparison of the mean overall accuracy response for each technology level

Table 4.9 Multiple comparisons between the mean overall accuracy responses for the technology levels

	mean		Video Teleconferencing	Chatroom	Email
		mean	4.437	4.188	3.500
Collocated	4.875		0.438	0.688*	1.375*
Video Teleconferencing	4.437			0.250	0.938*
Chatroom	4.188				0.688*

*p < 0.05

Phase had significant effect on perceived accuracy as shown in Table 4.7. The mean perceived accuracy for each phase is presented in Figure 4.3. From multiple comparison tests (Table 4.10), subjects had a significantly higher mean accuracy response in Phase 4 (mean = 4.266, sd = 1.116) than in the other phases (Phase 1: mean = 3.641, sd = 0.915; Phase 2: mean = 3.707, sd = 0.830; Phase 3: mean = 3.641, sd = 0.988).

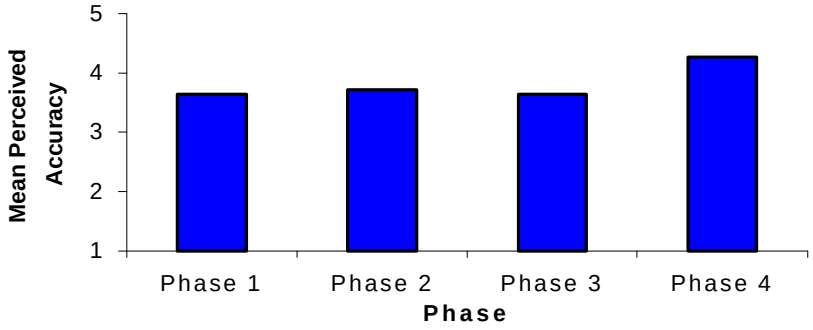

Figure 4.3 Comparison of the mean perceived accuracy in each phase

Table 4.10 Multiple comparisons of the mean accuracy response between phase levels

	mean		Phase 2	Phase 1	Phase 3
		mean	3.703	3.641	3.641
Phase 4	4.266		0.563*	0.625*	0.625*
Phase 2	3.703			0.063	0.063
Phase 1	3.641				0.000

*p < 0.05

The three-way interaction between phase, feedback cue, and technology was the only significant interaction from the analyses of perceived accuracy and overall perceived accuracy. Figure 4.4 through 4.7 show the mean perceived accuracy for each feedback and technology condition in each phase. Refer to Appendix A.13 for the multiple comparison tests. The mean accuracy perception when subjects used the chatroom without a feedback cue was significantly lower in Phase 1 compared to Phases 2 and 4. Similarly, the mean perceived accuracy was significantly lower in Phase 3 compared to Phase 4 when subjects used the chatroom without a feedback cue. When subjects used collocated communication both with and without a feedback cue the mean perceived accuracy was significantly higher in Phase 4 compared to Phases 1 and 2. The mean perceived accuracy was significantly higher in Phase 4 compared to Phase 3 when subject used video teleconferencing with a feedback cue.

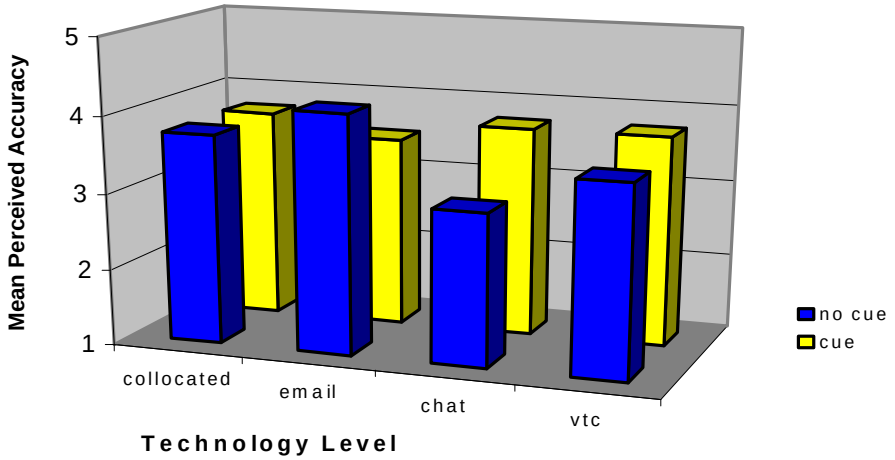

Figure 4.4 Mean perceived accuracy for each experimental condition in phase 1

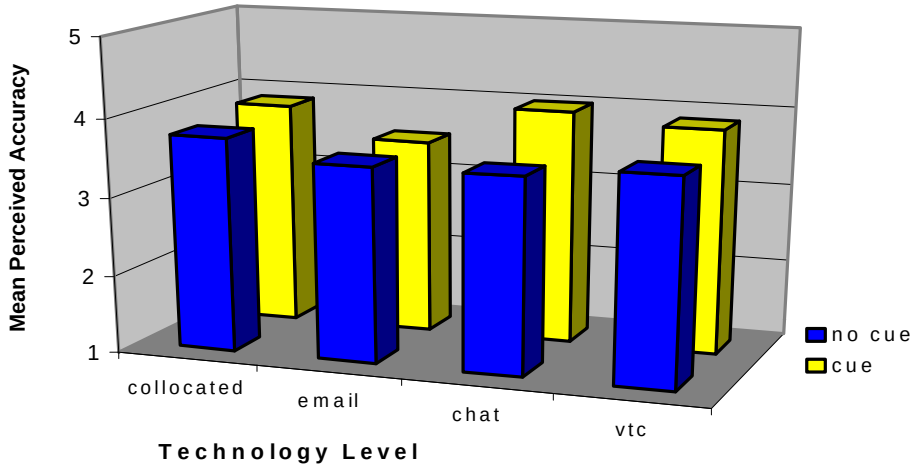

Figure 4.5 Mean perceived accuracy for each experimental condition in phase 2

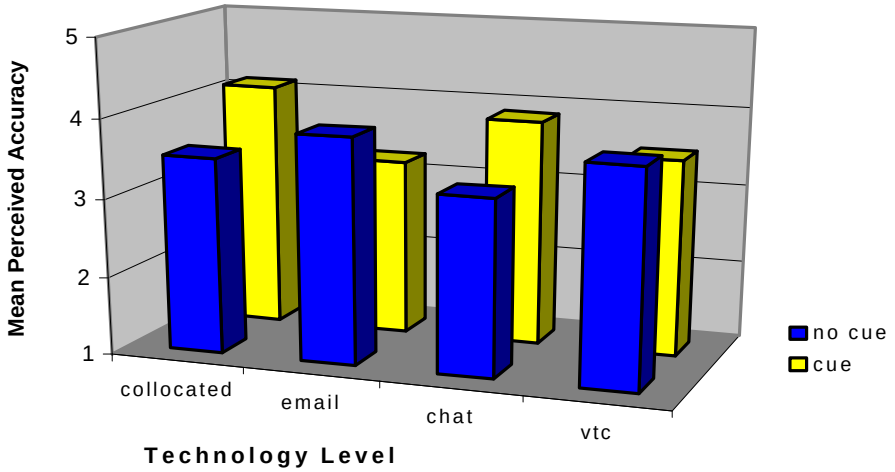

Figure 4.6 Mean perceived accuracy for each experimental condition in phase 3

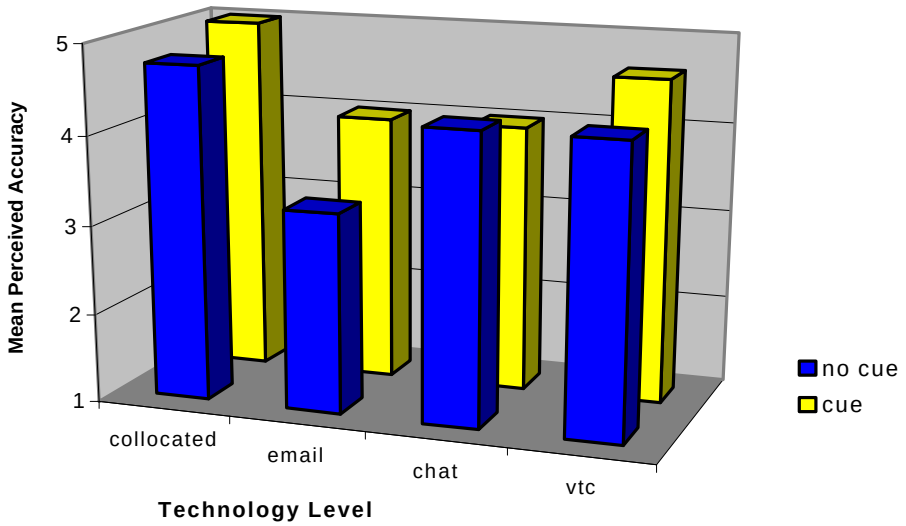

Figure 4.7 Mean perceived accuracy for each experimental condition in phase 4

4.2.3 Perceived Understanding

Tables 4.11 and 4.12 summarize the ANOVA results for the analysis of perceived accuracy analyzed by phase and for the overall process, respectively. While feedback was not significant, the mean perceived understanding in conditions with a feedback cue (mean = 4.062, sd = 0.771) was slightly higher than the mean perceived understanding in conditions without a feedback cue (mean = 3.969, sd = 0.922). For the overall perceived understanding data, the means were similar (no feedback cue: mean = 4.531, sd = 0.621; feedback cue: mean = 4.563, sd = 0.619).

Table 4.11 ANOVA summary table for the understanding response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	31.750	4.536		
Within					
P	3	21.812	7.271	7.314	0.002*
PxS	21	20.875	0.994		
C	1	0.563	0.563	1.212	0.307
CxS	7	3.250	0.464		
T	3	2.906	0.969	1.844	0.170
TxS	21	11.031	0.525		
PxC	3	1.187	0.396	1.511	0.241
PxCxS	21	5.500	0.262		
PxT	9	9.344	1.038	3.082	0.004*
PxTxS	63	21.219	0.337		
CxT	9	2.781	0.927	0.879	0.468
CxTxS	21	22.156	1.055		
PxCxT	9	5.344	0.594	1.545	0.152
PxCxTxS	63	24.219	0.384		
Total	255	183.938			

* $p < 0.01$

Table 4.12 ANOVA summary table for the overall understanding response

Source	Df	SS	MS	F	p-value
Between					
S	7	11.234	1.605		
Within					
C	1	0.016	0.016	0.046	0.836
CxS	7	2.359	0.337		
T	3	2.422	0.807	4.578	0.013*
TxS	21	3.703	0.176		
CxT	9	0.297	0.099	0.543	0.658
CxTxS	21	3.828	0.182		
Total	63	23.859			

*$p < 0.05$

From the analysis of all phases, technology was not significant. While the differences were not significant, the mean perceived understanding was highest in collocated communication (mean = 4.188, sd = 0.732) followed by the chatroom (mean = 4.016, sd = 0.934), video teleconferencing (mean = 3.953, sd = 0.898), and email (mean = 3.906, sd = 0.811).

Technology significantly affected the overall understanding response. Figure 4.8 shows the mean understanding response for each technology level and the multiple comparison tests are reported in Table 4.13. Subjects' perceived their understanding to be lower when they used email (mean = 4.25, sd = 0.683) than when they used either the chatroom (mean = 4.750, sd = 0.447) or collocated communication (mean = 4.687, sd = 0.479). When subjects used video teleconferencing (mean = 4.5, sd = 0.730) their perceived level of understanding was not significantly different from the other technology levels.

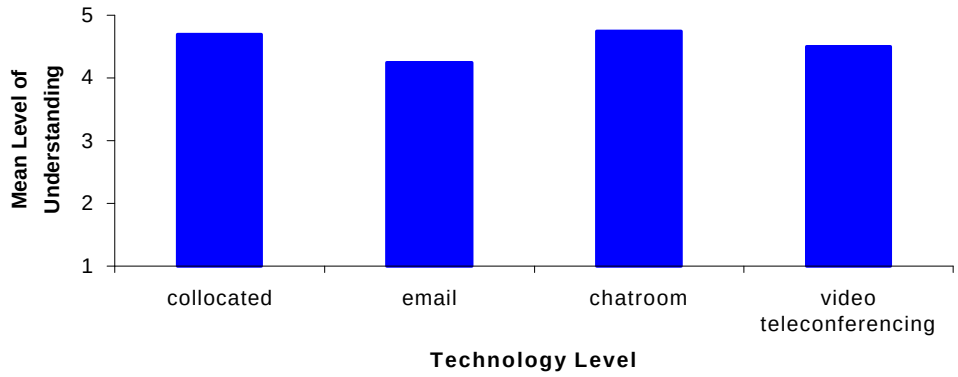

Figure 4.8 Mean overall understanding response for technology levels

Table 4.13 Multiple comparisons of the mean overall understanding responses for technology levels

	mean		Collocated	Video Teleconferencing	Email
	mean	mean	4.687	4.500	4.250
Chatroom	4.750		0.063	0.250	0.500*
Collocated	4.687			0.188	0.438*
Video Teleconferencing	4.500				0.250

*p < 0.05

Phase was significantly affected the subjects' understanding response. Figure 4.9 portrays the mean perceived accuracy for each phase. From the multiple comparison tests in Table 4.14, the mean understanding response was significantly higher in Phase 4 (mean = 4.500, sd = 0.797) than in the other phases (Phase 1: mean = 3.906, sd = 0.706; Phase 2: mean = 3.937, sd = 0.687; Phase 3: mean = 3.719, sd = 0.983).

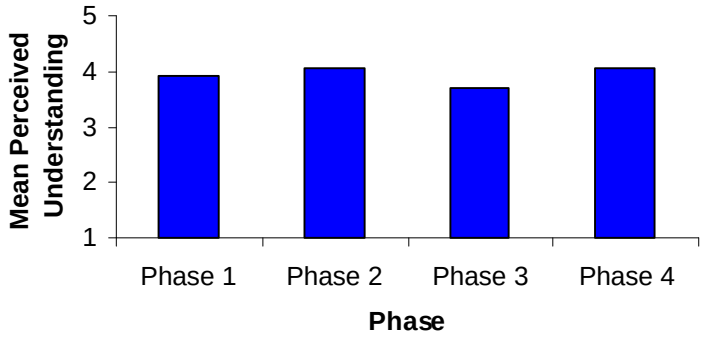

Figure 4.9 Comparison of the mean perceived understanding for each phase

Table 4.14 Multiple comparisons between the mean understanding response for each phase

	mean		Phase 2	Phase 1	Phase 3
	mean	mean	3.937	3.906	3.719
Phase 4	4.500		0.563*	0.594*	0.781*
Phase 2	3.937			0.031	0.219
Phase 1	3.906				0.188

*p < 0.05

The only interaction that was significant in the analysis of the perceived understanding was the interaction between phase and technology level. The mean understanding response is shown in Figure 4.10. From this figure, it appears that the perceived understanding is relatively the same for all phases when email was used. From multiple comparisons (Table A.14.1 in Appendix A.14), the mean response using collocated communication in Phase 4 was significantly higher than the mean response of the other conditions except for the chatroom and video teleconferencing during Phase 4. The same was true for the chatroom during Phase 4. Video teleconferencing during Phase 4 had a significantly higher mean response than the other conditions except for email in Phase 1, the chatroom in Phase 2 and collocated

communication and the chatroom in Phase 4. The descriptive statistics are reported in (Table A.14.2 in Appendix A.14).

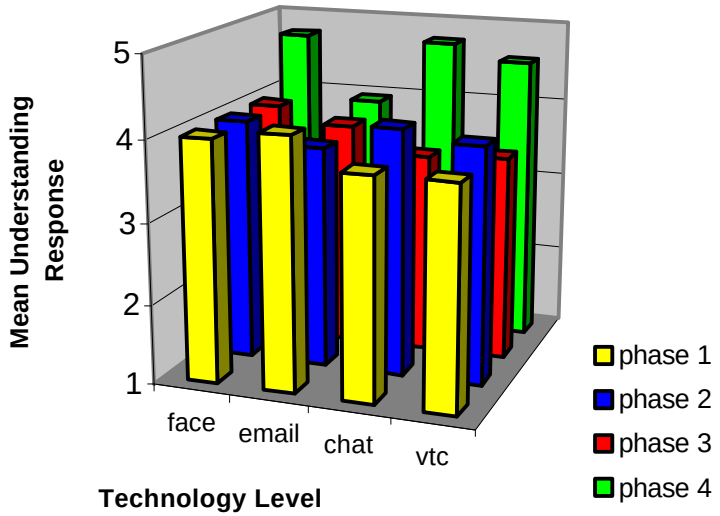

Figure 4.10 Mean understanding response for the interaction between phase and technology

4.2.4 Tutor's Perception of Subject Understanding

After each trial, the tutor responded to a question about his perception of how well the subject understood the math problem. Feedback cue and the interaction between technology and feedback cue level did not significantly affect the tutor's perception, however, technology level did affect the tutor's perception as reported in Table 4.15. Figure 4.11 contains the tutor's mean perception for each technology level. From the multiple comparison tests, Table 4.16, the tutor perceived subjects' understanding was significantly lower when using email (mean = 3.375, sd = 1.148) compared to the other technology levels (collocated: mean = 4.438, sd = 0.512; chatroom: mean = 4.125, sd = 1.025; and video teleconferencing: mean = 4.250, sd = 0.931).

Table 4.15 ANOVA summary table for tutor's perception of subjects' understanding

Source		df	SS	MS	F	p-value
Between						
	S	7	20.234	2.891		
Within						
	C	1	0.391	0.391	0.785	0.405
	CxS	7	3.484	0.498		
	T	3	10.422	3.474	3.524	0.033*
	TxS	21	20.703	0.986		
	CxT	3	0.172	0.057	0.161	0.921
	CxTxS	21	7.453	0.355		
Total		63	62.859			

*$p < 0.05$

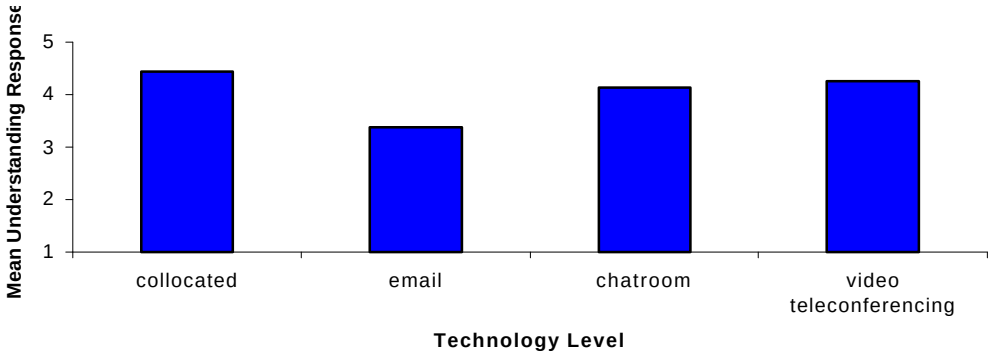

Figure 4.11 Comparison of the mean tutor's perception of subjects' understanding

Table 4.16 Multiple comparisons of mean perceived understanding for technology levels

			Video Teleconferencing	Chatroom	Email
	mean	mean	4.250	4.125	3.375
Collocated	4.438		0.188	0.313	1.063*
Video Teleconferencing	4.250			0.125	0.875*
Chatroom	4.125				0.750*

*$p < 0.05$

4.3 Process Time

Process time was measured as the time required for the subject to complete each phase. Timing started when the tutor either began giving instructors or after he had sent written instructions. The timing ended when the subject told the tutor he or she was finished with the task. No time limit was set for individual phases. However, the participants had one hour to complete the overall task and the associated questionnaires.

Appendix A.7 contains the process times collected in this research. In the situation when subjects did not complete a task, the data point is denoted with an asterisk (*). The analysis for process time was conducted excluding incomplete data. The argument to exclude the incomplete trial data was that the time it would have taken for the participants to complete the task is an unknown. Analysis of variance was used to determine statistical significance as shown in Table 4.17 for the analysis by phase and Table 4.18 for the analysis of the overall process.

While feedback cue was not significant in either analysis, there was a slight trend in the data. When analyzed by phase, conditions with a feedback (mean = 9.927, sd = 8.477) took slight less time to complete than conditions without a feedback cue (mean = 10.683, sd = 9.227). There was a similar trend in the overall analysis (no feedback cue: mean = 42.107, sd = 11.295; feedback cue: mean = 39.741, sd = 13.617).

Table 4.17 ANOVA summary table for time to complete the task in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	239.670	34.239		
Within					
P	3	3202.588	1067.529	16.894	<0.001*
PxS	21	1326.988	63.190		
C	1	36.971	36.971	1.662	0.238
CxS	7	155.701	22.243		
T	3	1088.278	362.759	28.334	<0.001*
TxS	21	268.872	12.803		
PxC	3	171.920	57.307	0.988	0.418
PxCxS	21	1217.851	57.993		
PxT	9	287.206	31.912	0.436	0.910
PxTxS	62	4541.703	73.253		
CxT	3	11.309	3.770	0.130	0.941
CxTxS	21	608.708	28.986		
PxCxT	9	195.186	21.687	0.295	0.973
PxCxTxS	54	3966.154	73.447		
Total	245	17319.105			

*p < 0.01

Table 4.18 ANOVA summary table for the overall process time

Source	df	SS	MS	F	p-value
Between					
S	7	1846.770	263.824		
Within					
C	1	50.726	50.726	0.725	0.423
CxS	7	489.504	69.929		
T	3	3884.620	1294.873	21.248	<0.001*
TxS	20	1218.847	60.942		
CxT	3	364.067	121.356	1.772	0.202
CxTxS	13	890.100	68.469		
Total	54	9035.664			

*p < 0.01

Technology significantly affected the process time in the analysis by phase and for the overall process. Figure 4.12 contains a comparison of the mean process time for each technology level. Collocated communication (mean = 7.547, sd = 6.076) and video teleconferencing (mean = 9.361, sd = 9.310) were significantly faster than email (mean = 13.034, sd = 10.422) as shown in Table 4.19. Collocated communication was also significantly faster than the chatroom (mean = 11.484, sd = 8.392).

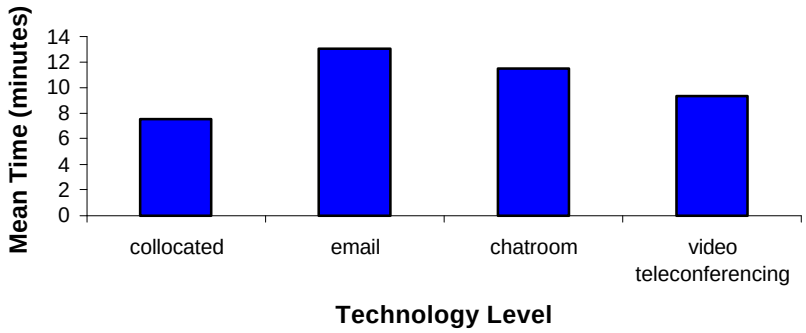

Figure 4.12 Comparison of the mean process times for technology levels

Table 4.19 Multiple comparisons of the mean process times between technology levels

		Video Teleconferencing	Chatroom	Email
	mean	9.361	11.484	13.034
	mean			
Collocated	7.547	1.814	3.937*	5.487*
Video Teleconferencing	9.361		2.123	3.673*
Chatroom	11.484			1.550

*p < 0.05

The mean overall process time for each technology level is graphed in Figure 4.13. To determine which technology levels were significantly different, multiple comparison tests were performed (Table 4.20). The mean process time for collocated communication (mean = 30.188 minutes, sd = 9.225) was significantly faster than the mean process time for both the chatroom (mean = 46.714 minutes, sd = 8.194) and email (mean = 53.167 minutes, sd = 4.707). Similarly, video teleconferencing (mean = 36.692 minutes, sd = 11.564) was significantly faster than either email or the chatroom.

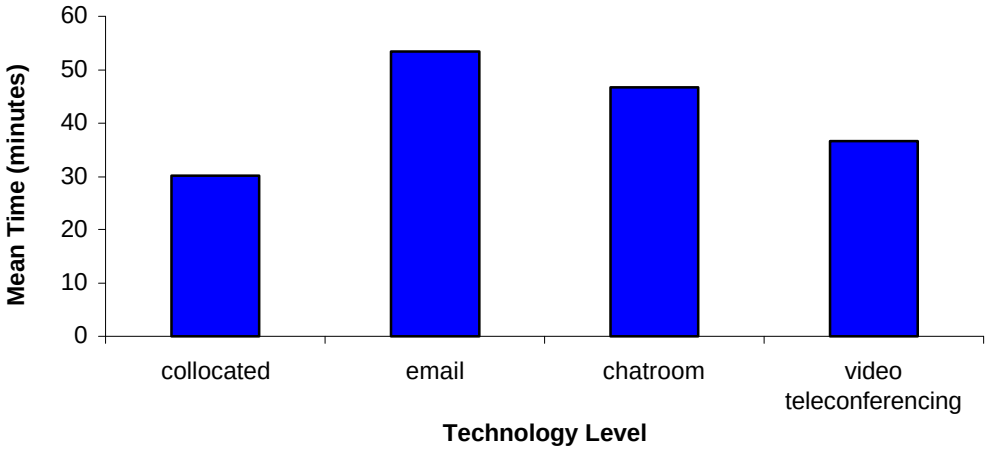

Figure 4.13 Comparison of the mean overall process times for technology levels

Table 4.20 Multiple comparisons of the mean overall process times between technology levels

			Video Teleconferencing	Chatroom	Email
	mean	mean	36.692	46.714	53.167
Collocated	30.188		6.505	16.527*	22.979*
Video Teleconferencing	36.692			10.022*	16.474*
Chatroom	46.714				6.452

*p < 0.05

Phase significantly affected process time and the mean process time for each phase is summarized in Figure 4.14. From the multiple comparison tests (Table 4.21), the mean time required to complete Phase 1 (mean = 4.000, sd = 2.906) was significantly faster than the mean times to complete the other phases (Phase 2: mean = 10.813, sd = 8.450; Phase 3: mean = 13.452, sd = 13.452; Phase 4: mean = 13.768, sd = 8.505). In addition, the mean process time in Phase 2 was significantly faster than the mean process time in Phase 4.

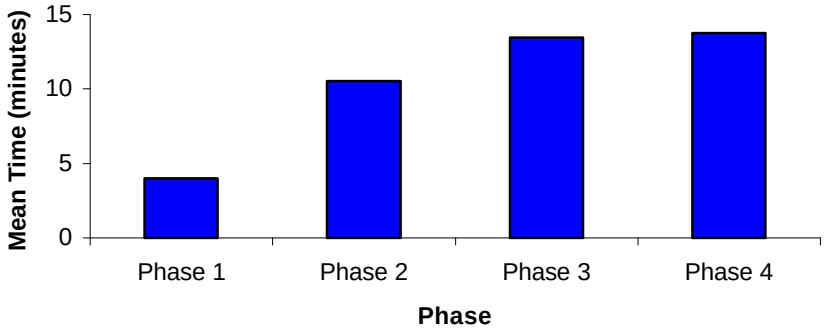

Figure 4.14 Comparison of the mean time to complete each phase

Table 4.21 Multiple comparisons of mean process times between phases

			Phase 2	Phase 3	Phase 4
	mean	mean	10.813	13.452	13.738
Phase 1	4.000		6.531*	9.452*	9.768*
Phase 2	10.813			2.920	3.237*
Phase 3	13.452				0.316

*p < 0.05

The two-way and three-way interactions between feedback cue, technology, and phase level were not significant in the analysis of process time by phase. Similarly, the interaction between feedback cue and technology level was not significant in the analysis of the overall process time.

4.4 User Satisfaction Ranks

To determine the users' satisfaction, subjects ranked the eight experimental conditions from 1, the best, to 8, the worst. The subjects ranked the experimental conditions for each phase and for the overall process after they experienced all experimental conditions. In addition, subjects ranked the experimental conditions base on ease of use, efficiency, effectiveness, and level of comfort for working with the tutor. Refer to Appendix A.15 for the ranks collected in this research.

Friedman's test was conducted to determine statistical significance for the ranked orders of the main effects. However, Friedman's test could not be used to evaluate interactions; therefore, analysis of variance was performed to determine significance of the interaction between technology and feedback cue level. Friedman's test statistic was calculated for each of the individual phases to determine if the treatment affected the satisfaction with an individual phase. In addition, Friedman's test statistic was calculated for the overall satisfaction ranks.

All of the ranked subjective variables were strongly correlated. Therefore, only the satisfaction ranks will be reported. Refer to Appendix A.16 for the correlation matrix for the analysis by phase and the overall analysis. Refer to Appendix A.17 for the analysis of the ease of use, efficiency, effectiveness, and comfort ranks.

4.4.1 User Satisfaction with Technology

Table 4.22 contains the correlation matrix for the subjects' technology satisfaction in each phase and overall. Because there was a strong correlation between phases and overall, only the analysis for Phase 1 was reported. Refer to Appendix A.18 for the analysis for Phases 2 through 4 and overall.

Table 4.22 Correlation matrix for technology satisfaction ranks between each phase and the overall process

	Phase 1	Phase 2	Phase 3	Phase 4
Phase 2	0.893			
Phase 3	0.719	0.784		
Phase 4	0.667	0.798	0.949	
Overall	0.850	0.968	0.821	0.827

In Phase 1, there was a significant difference in the satisfaction ranks for at least one technology level, $S(3) = 8.44$, $p = 0.038$ (adjusted for ties, $S(3) = 9.00$, $p = 0.030$). The satisfaction ranked sum for each technology level is shown in Figure 4.15. Multiple comparison tests were performed to determine which technology levels were significantly different as reported in Table 4.23. Subjects were significantly more satisfied with collocated communication (mean = 1.625, sd = 1.061) than either email (mean = 3.312, sd = 0.458) or video teleconferencing (mean = 2.938, sd = 1.148). Subjects were significantly more satisfied in the chatroom (mean = 2.125, sd = 0.835) compared to email.

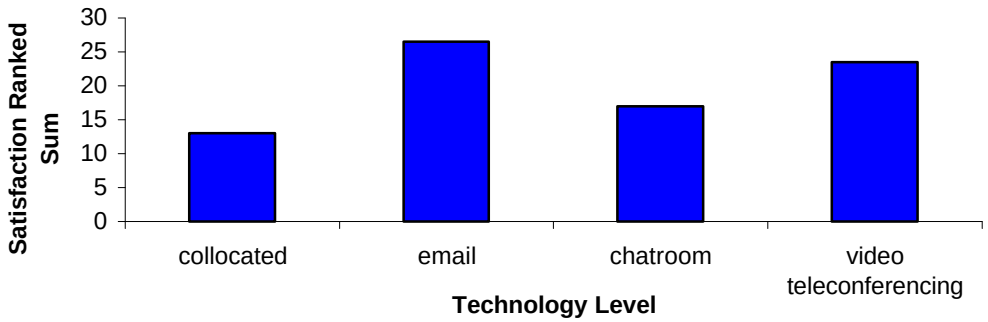

Figure 4.15 Comparison of the satisfaction ranked sums for technology levels in phase 1

Table 4.23 Multiple comparisons of satisfaction ranked sums for technology levels in phase 1

		Chatroom	Video Teleconferencing	Email
	ranked sum	17.0	23.5	26.5
	ranked sum			
Collocated	13.0	4.0	10.5*	13.5**
Chatroom	17.0		6.5	9.5*
Video Teleconferencing	23.5			3.0

*p < 0.05
**p < 0.01

4.4.2 User Satisfaction with Feedback Cue

In Phase 1, there was a significant difference between the satisfaction ranks of the two feedback cue levels, S(1) = 4.5, p = 0.034. The ranked sums, which were equivalent in all phases, are shown in Figure 4.16. Therefore, subjects were more satisfied in conditions without the feedback cue (mean = 1.125, sd = 0.354) than in conditions with the feedback cue (mean = 1.875, sd = 0.354).

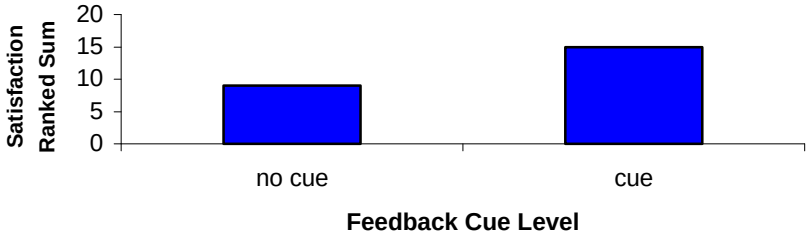

Figure 4.16 Comparison of the mean satisfaction ranks for the feedback cue levels in phase 1

4.4.3 Interaction between Technology and Feedback Cue

The interaction between technology and feedback cue was not significant in the satisfaction analysis for all phases and the overall process. Refer to Appendix A.18 for the ANOVA tables that contain the results for the interaction between technology and feedback cue level.

4.5 Supplemental Questionnaire Responses

In the supplemental questionnaires (Appendix A.3), subjects responded to questions regarding satisfaction, ease of use, efficiency, and effectiveness. Refer to Appendix A.8 for the complete list of responses to the questions.

A multivariate analysis of variance was conducted to determine the effect of the dependent variables on the main effects and interactions. From this analysis, technology was significantly effected by satisfaction, ease of use, efficiency, and effectiveness as shown in Table 4.24. From the analysis on the overall process, technology was significantly effected by overall satisfaction, overall ease of use, overall efficiency, and overall effectiveness as shown in Table 4.25. For the complete MANOVA results refer to Appendix A.19. Univariate ANOVAs were performed for each dependent variable.

Table 4.24 Multivariate analysis of variance to test the affect of perceptions of satisfaction, ease of use, efficiency, and effectiveness on the main effects and interactions

	F	p-value
Technology	2.752	0.006*
Feedback	1.378	0.382
Phase	1.057	0.415
Technology x Feedback	1.298	0.250
Phase x Feedback	0.773	0.675
Phase x Technology	0.816	0.764
Phase x Feedback x Technology	1.283	0.141

*$p < 0.05$

Table 4.25 Multivariate analysis of variance to test the affect of perceptions of overall satisfaction, overall ease of use, overall efficiency, and overall effectiveness on the main effects and the interaction

	F	p-value
Technology	2.227	0.024*
Feedback	1.431	0.368
Technology x Feedback	0.864	0.587

*$p < 0.05$

There was a strong correlation between the satisfaction, ease of use, efficiency and effectiveness responses. Refer to Appendix A.20 for the correlation matrix for the analysis by phase and the overall analysis. The results for the satisfaction response will be reported. Refer to Appendix A.21 for the analysis of the ease of use, efficiency, and effectiveness responses.

Feedback did not significantly affect satisfaction in either the analysis by phase (Table 4.26) or the analysis for the overall process (Table 4.27). Although the difference was not significant, mean accuracy and mean overall accuracy was higher in conditions with the feedback cue (by phase: mean = 3.688, sd = 1.025; overall: mean = 3.719, sd = 1.054) compared to conditions without the feedback cue (by phase: mean = 3.539, sd = 1.122; overall: 3.500, sd = 1.295).

Table 4.26 ANOVA summary table for satisfaction response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	95.871	13.696		
Within					
P	3	0.324	0.108	0.369	0.776
PxS	21	6.145	0.293		
C	1	1.410	1.410	3.439	0.106
CxS	7	2.871	0.410		
T	3	36.168	12.056	5.779	0.005*
TxS	21	43.801	2.086		
PxC	3	0.137	0.046	0.169	0.917
PxCxS	21	5.707	0.272		
PxT	9	3.285	0.365	1.174	0.328
PxTxS	63	19.621	0.311		
CxT	3	14.731	4.910	2.477	0.089
CxTxS	21	41.613	1.982		
PxCxT	9	4.535	0.504	1.714	0.104
PxCxTxS	63	18.496	0.294		
Total	255	294.715			

* $p < 0.01$

Table 4.27 ANOVA summary table for the overall satisfaction response

Source	df	SS	MS	F	p-value
Between					
S	7	21.109	3.016		
Within					
C	1	0.766	0.766	1.304	0.291
CxS	7	4.109	0.587		
T	3	24.967	8.099	7.974	0.001*
TxS	21	21.328	1.016		
CxT	3	2.797	0.932	1.526	0.237
CxTxS	21	12.828	0.611		
Total	63	87.234			

*$p = 0.001$

Technology was significant in the analysis by phase and for the overall process. The mean satisfaction response for each technology level is shown in Figure 4.17. From the analysis by phase, the mean response for each technology level was significantly different as shown in Table 4.28. The mean satisfaction response was the highest for collocated communication (mean = 4.109, sd = 0.819) followed by the chatroom (mean = 3.781, sd = 0.934), video teleconferencing (mean = 3.469, sd = 1.126), and email (mean = 3.094, sd = 1.137).

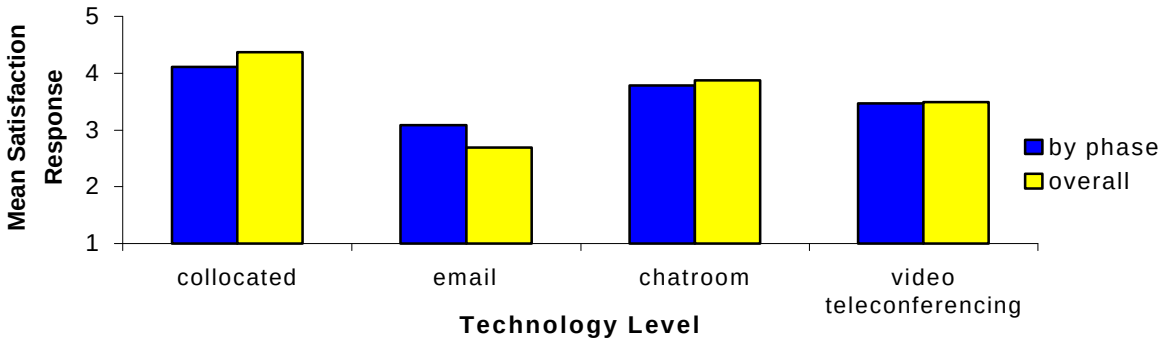

Figure 4.17 Mean satisfaction responses for technology levels

Table 4.28 Multiple comparisons of the mean satisfaction response for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.781	3.469	3.094
	mean				
Collocated	4.109		0.328*	0.641*	1.016*
Chatroom	3.781			0.313*	0.688*
Video Teleconferencing	3.469				0.375*

*p < 0.05

From the overall analysis (Table 4.29), satisfaction with email (mean = 2.688, sd = 1.250) was significantly lower than satisfaction in the other technology levels (collocated: mean = 4.375, sd = 0.619; chatroom: mean = 3.875, sd = 0.885; and video teleconferencing: mean = 3.500, sd = 1.211). Subjects were significantly more satisfied when they used collocated communication compared to when they used video teleconferencing.

Table 4.29 Multiple comparisons of the mean overall satisfaction response for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.875	3.500	2.688
	mean				
Collocated	4.375		0.500	0.875*	1.688*
Chatroom	3.875			0.375	1.188*
Video Teleconferencing	3.500				0.813*

*p < 0.05

Phase and the two and three-way interactions between phase, feedback cue, and technology were not significant in the analysis of the satisfaction response. Similarly, the interaction between technology and feedback cue level was not significant in the analysis of the overall satisfaction response.

4.6 Tutor's Perceptions

4.6.1 Supplemental Ranked Orders

After each trial, the tutor completed a questionnaire. In addition, once all trials were complete, the tutor rank ordered the experimental conditions according to ease of use, efficiency, and effectiveness. For a complete list of the tutor's ranks, refer to Appendix A.22. All of the ranks were strongly correlated as shown in Table 4.30. Therefore, only the results for satisfaction will be reported. Please refer to Appendix A.23 for the results of ease of use, efficiency, and effectiveness ranks.

Table 4.30 Pearson product moment for satisfaction, ease of use, efficiency, and effectiveness ranks

	Ease of Use	Efficiency	Effectiveness
Satisfaction	0.943	0.986	0.967
Ease of Use		0.976	0.919
Efficiency			0.962

To determine the technology condition the tutor was most satisfied in, the rank of each technology condition with and without feedback cues was summed. The technology condition with the lowest summed rank was the condition in which the tutor had the highest satisfaction. For Phases 1, 2, 4, and overall, ranked collocated communication as the most satisfying (ranked sum = 3), followed by video teleconferencing (ranked sum = 7), chatroom (ranked sum = 11), and email (ranked sum = 15). In Phase 3, the order of preferences did not change but the ranked sum for video teleconferencing communication increased to 8 and the ranked sum for chatroom communication decreased to 10.

To determine the feedback cue level in which the tutor was most satisfied, the rank of each feedback cue level was summed over the technology levels. In Phases 1, 2, 4, and overall, the tutor was more satisfied in conditions with feedback cues (ranked sum = 17) than in conditions without feedback cues (ranked sum = 19). In Phase 3, the ranked sums slightly changed (no feedback cue: ranked sum = 20 and feedback cue: ranked sum = 16).

For collocated communication, the tutor was more satisfied in the conditions without feedback cue than in the conditions with feedback cues. When the tutor used email, the chatroom, or video teleconferencing, he was more satisfied with feedback cues than without feedback cues. These results occurred in all phases and in the overall process.

4.6.2 Supplemental Questionnaire Responses

After each trial was complete, the tutor responded to questions about his satisfaction, the ease of use, efficiency, and effectiveness of each experimental condition. A multivariate analysis of variance was conducted on the tutor's satisfaction, ease of use, efficiency, and effectiveness responses. From this analysis, technology was significant as shown in Table 4.31. For the complete MANOVA results refer to Appendix A.24. Univariate ANOVAs were performed for each dependent variable.

Table 4.31 Multivariate analysis of variance to test the affect of the tutor's satisfaction, ease of use, efficiency, and effectiveness on main effects and the interaction

	F	p-value
Technology	11.297	<0.001*
Feedback	0.547	0.714
Technology x Feedback	1.088	0.390

*p < 0.05

There was a strong correlation between the satisfaction, ease of use, efficiency and effectiveness responses as shown in Table 4.32. The results for satisfaction will be reported. Refer to Appendix A.25 for the results for ease of use, efficiency, and effectiveness responses.

Table 4.32 Pearson product moment for the tutor's satisfaction, ease of use, efficiency and effectiveness response

	Ease of Use	Efficiency	Effectiveness
Satisfaction	0.904	0.875	0.918
Ease of Use		0.857	0.859
Efficiency			0.899

Feedback cue and the interaction between feedback cue and technology were not significant as reported in Table 4.33. Technology significantly affected the tutor's satisfaction response. The tutor's mean satisfaction response for each technology level is graphed in Figure 4.18. From Table 4.34, the tutor's mean satisfaction response for email (mean = 2.188, sd = 0.911) was significantly lower than the mean satisfaction responses for the other technology levels (collocated: mean = 4.875, sd = 0.342; chatroom: mean = 4.500, sd = 0.633; video teleconferencing: mean = 4.063, sd = 0.854). In addition the tutor was significantly more satisfied when he used collocated communication compared to when he used video teleconferencing.

Table 4.33 ANOVA summary table for the tutor's satisfaction response

Source		df	SS	MS	F	p-value
Between						
	S	7	8.188	1.170		
Within						
	C	1	0.250	0.250	0.700	0.430
	CxS	7	2.500	0.357		
	T	3	68.313	22.771	68.928	<0.001*
	TxS	21	6.937	0.330		
	CxT	3	2.125	0.708	1.337	0.289
	CxTxS	21	11.125	0.530		
Total		63	99.438			

*p < 0.001

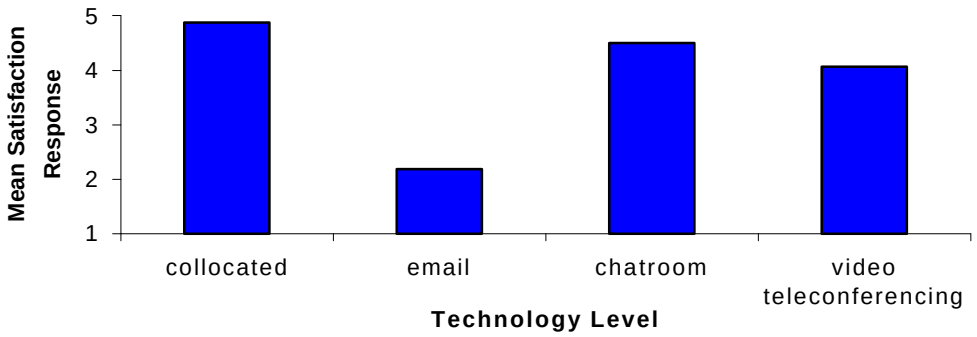

Figure 4.18 Comparison of the tutor's mean satisfaction response in each technology level

Table 4.34 Multiple comparisons of the tutor's mean satisfaction response for technology levels

		Chatroom	Video Teleconferencing	Email
	mean	4.500	4.063	2.188
	mean			
Collocated	4.875	0.375	0.812*	2.687*
Chatroom	4.500		0.437	2.312*
Video Teleconferencing	4.063			1.875*

*$p < 0.05$

4.7 Analysis of the Experimental Process

4.7.1 Accuracy

To study the process, ANOVA was performed to determine if accuracy was affected by ordering and/or repeated exposure to the tutoring process. In Phases 1 and 2, the main effects were not significant as reported in Table A.26.1 and Table A.26.2 (Appendix A.26), respectively. In Phase 3, order and subject were significant as shown in Table 4.35. The mean accuracy for the order is shown in Figure 4.19. Re-analyzing the data for accuracy excluding the incomplete trial data, order and subject remained significant as reported in Table 4.36. Figure 4.20 contains a graph of the mean accuracy excluding the incomplete trial data.

Table 4.35 ANOVA summary table for accuracy in phase 3

Source	df	SS	MS	F	p-value
O	7	125.250	17.893	3.400	0.006*
S	7	139.000	19.857	3.774	0.003*
T	7	32.750	4.679	0.889	0.524
R	42	221.000	5.262		
Total	63	518.00			

*$p < 0.01$

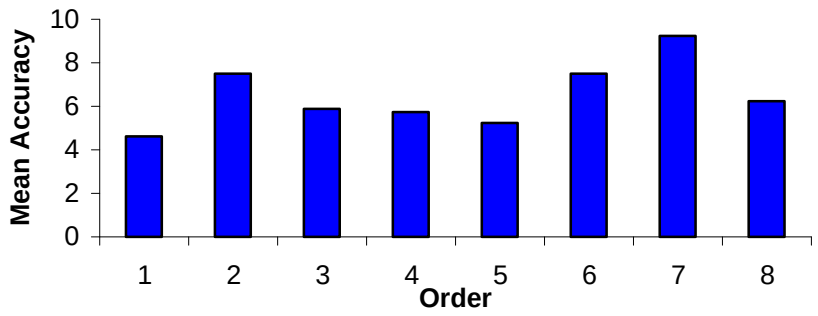

Figure 4.19 Comparison of mean accuracy of phase 3 by order

Table 4.36 ANOVA summary table for accuracy in phase 3 (excluding incomplete trials)

Source	df	SS	MS	F	p-value
O	7	118.535	16.934	3.123	0.010*
S	7	124.480	17.783	3.279	0.008*
T	7	30.221	4.317	0.796	0.595
R	40	216.914	5.423		
Total	61	490.150			

*$p \leq 0.01$

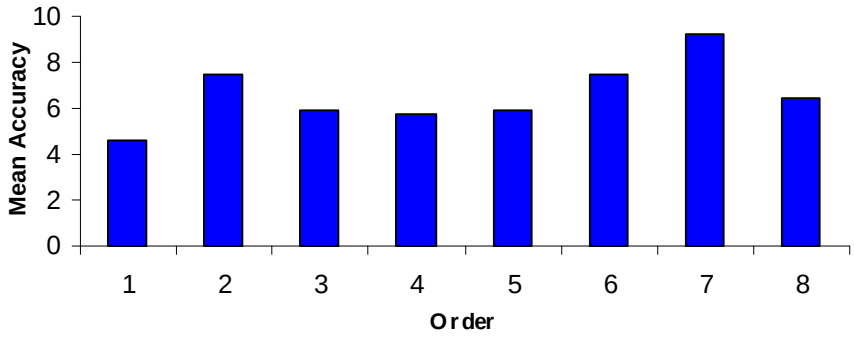

Figure 4.20 Comparison of mean accuracy excluding incomplete trials in phase 3 by order

In Phase 4, accuracy was analyzed including all data (Table 4.37) and excluding incomplete trial data (Table A.26.3). From the ANOVA, order was the only significant effect. Figure 4.21 contains a graph of the mean accuracy for order. The main effects were not significant when accuracy was analyzed excluding incomplete trial data.

Table 4.37 ANOVA summary table for accuracy in phase 4

Source	df	SS	MS	F	p-value
O	7	51.500	7.357	2.462	0.033*
S	7	11.250	1.607	0.538	0.801
T	7	43.500	6.214	2.080	0.067
R	42	125.500	2.988		
Total	63	231.750			

*$p < 0.05$

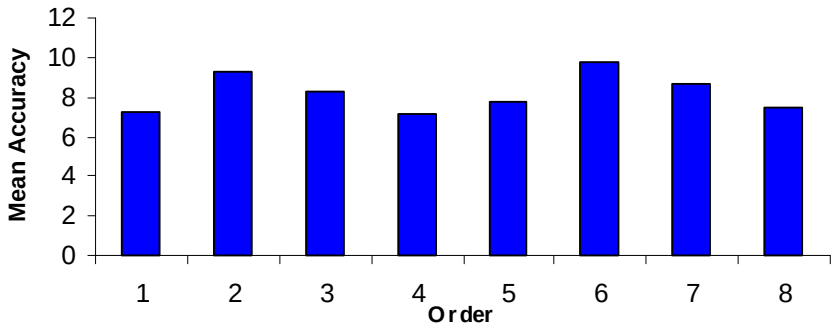

Figure 4.21 Comparison of mean accuracy of phase 4 by order

From Table 4.38, order was the only significant effect. A graph of the mean overall accuracy for order is shown in Figure 4.22. From Table A.26.4, the ANOVA for overall accuracy excluding incomplete trials, the main effects were not significant.

Table 4.38 ANOVA summary table for accuracy in the overall tutoring process

Source	df	SS	MS	F	p-value
O	7	648.484	92.641	2.417	0.036*
S	7	501.984	71.712	1.871	0.099
T	7	399.734	57.105	1.490	0.197
R	42	1609.906	38.331		
Total	63	3160.11			

*$p < 0.05$

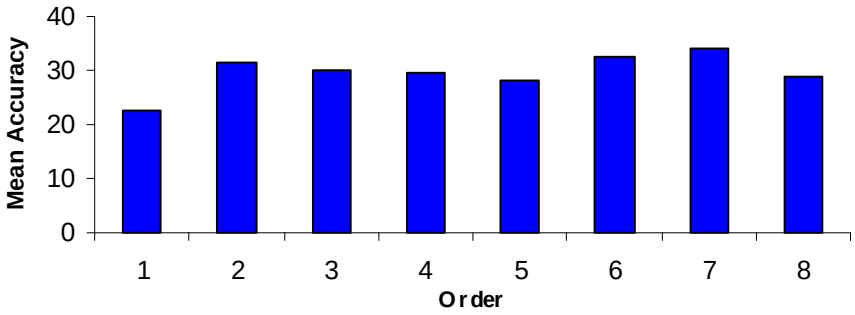

Figure 4.22 Comparison of overall mean accuracy by order

4.7.2 Process Time

Process effects on process time were analyzed. In the event of a significant ordering effect, the effect of the expected process time versus the actual process time was analyzed. The mathematics instructor determined the expected times for phases in each math problem as reported in (Appendix A.2). To determine if the expected times had an effect on ordering, analysis of variance was conducted on the absolute value of the difference between the expected and observed time. The absolute value of the difference was taken to avoid the potential canceling effect of going under or exceeding the expected time.

In phase 1, order was significant as shown in Table 4.39. The mean times for the order are shown in Figure 4.23. Because order was significant, an ANOVA for the difference between the expected and observed process time was conducted. Order was again significant as shown in Table 4.40. The mean order differences are shown in Figures 4.24.

Table 4.39 ANOVA summary table for time to complete phase 1

Source	df	SS	MS	F	p-value
O	7	127.250	18.179	2.766	0.019*
S	7	42.250	6.036	0.918	0.502
T	7	86.500	12.357	1.880	0.097
R	42	276.000	6.571		
Total	63	532.00			

*p < 0.05

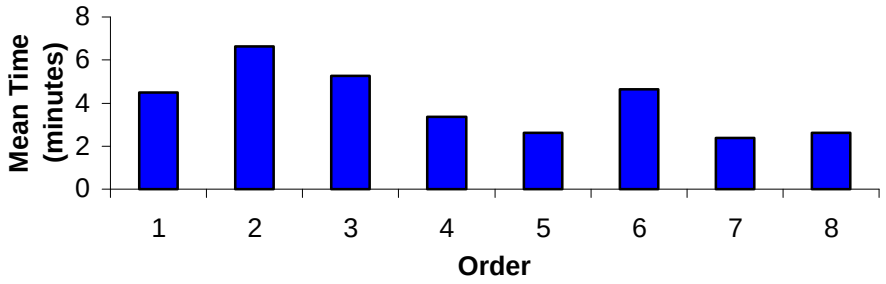

Figure 4.23 Comparison of mean times to complete phase 1 tasks by order

Table 4.40 Phase 1 ANOVA summary table for the difference between expected and observed process times

Source	df	SS	MS	F	p-value
O	7	442.500	63.214	13.546	0.000*
S	7	27.500	3.929	0.842	0.559
T	7	47.750	6.821	1.462	0.207
R	42	196.000	4.667		
Total	63	713.750			

*p < 0.01

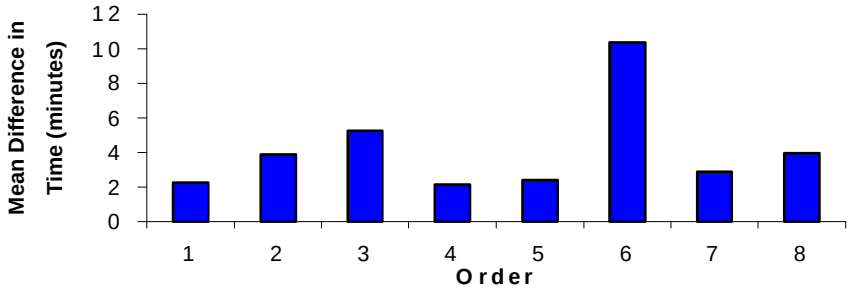

Figure 4.24 Phase 1 mean differences between expected and observed process times by order

In Phase 2, order, subject, and treatment were significant as reported in Table 4.41. The mean times for the order are shown in Figure 4.25. Because order was significant, an ANOVA for the difference between the expected and observed process time was conducted. Order was again significant as shown in Table 4.42. The mean order differences are shown in Figure 4.26.

Table 4.41 ANOVA summary table for time to complete phase 2

Source	df	SS	MS	F	p-value
O	7	1476.937	210.991	6.018	0.000*
S	7	776.188	110.884	3.162	0.009*
T	7	772.187	110.312	3.146	0.009*
R	42	1472.625	35.063		
Total	63	4497.938			

*p < 0.01

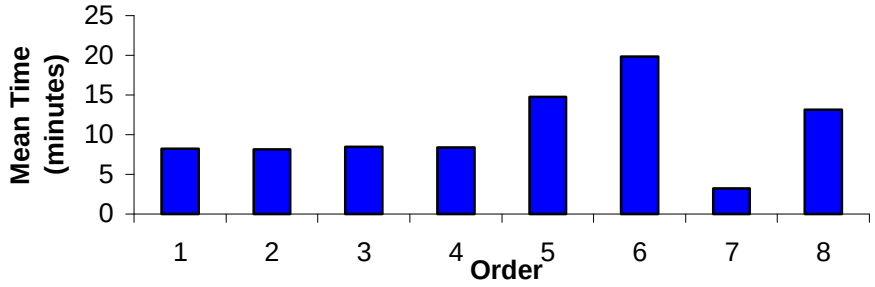

Figure 4.25 Comparison of mean times to complete phase 2 tasks by order

Table 4.42 Phase 2 ANOVA summary table the difference between expected and observed process times

Source	df	SS	MS	F	p-value
O	7	428.438	61.205	4.076	0.002*
S	7	176.688	25.241	1.681	0.140
T	7	145.188	20.741	1.381	0.238
R	42	630.625	15.015		
Total	63	1380.939			

*p < 0.01

Figure 4.26 Phase 2 mean differences between expected and observed process times by order

In Phase 3, order and subject were significant as reported in Table 4.43. The mean times for order are shown in Figure 4.27. Because order was significant, an ANOVA for the difference between the expected and observed process time was conducted. Order was not significant as shown in Table A.26.5.

Table 4.43 ANOVA summary table for time to complete phase 3

Source	df	SS	MS	F	p-value
O	7	3230.788	461.541	10.279	0.000**
S	7	845.599	120.800	2.690	0.022*
T	7	464.659	66.380	1.478	0.203
R	40	1796.081	44.902		
Total	61	6337.127			

*p < 0.05
**p < 0.01

Figure 4.27 Comparison of mean times to complete phase 3 tasks by order

As shown in Table A.26.6, the main effects were not significant in Phase 4. For the overall process time (Table 4.44), subject and treatment were both significant. However, order was not significant; therefore, no further analysis was conducted.

Table 4.44 ANOVA summary table for time to complete overall tutoring process

Source	df	SS	MS	F	p-value
O	7	682.927	97.561	1.846	0.111
S	7	1309.389	187.056	3.539	0.006*
T	7	4727.101	675.300	12.778	0.000*
R	33	1744.032	51.307		
Total	54	8463.449			

*p < 0.01

4.8 Supplemental Analysis of Phase

The mathematics instructor determined the expected times for phases in each math problem. Refer to Table A.2 (Appendix A.2) for the expected process times. To determine if the subjects met this expectation, one-way analysis of variance was performed on the absolute value of the difference between the expected and observed times for each phase as shown in Table 4.45. The absolute value of the

difference was taken to avoid the potential canceling effect of going under or exceeding the expected time. Because there was a significant difference between the phases for the time differences, multiple comparisons were conducted (Table 4.46). The mean time to complete Phase 1 (mean = 3.938 minutes, sd = 3.366) was significantly faster than the mean times to complete other phases (Phase 2: mean = 7.219 minutes, sd = 4.682; Phase 3: mean = 7.742 minutes, sd = 5.523; and Phase 4: 7.625 minutes, sd = 6.116).

Table 4.45 ANOVA table for the difference (D) between the expected and observed process times for all phases

Source	df	SS	MS	F	p-value
D	3	617.849	205.950	8.290	<0.001*
S/D	242	6011.683	24.842		
Total	245	6629.533			

*p < 0.01

Table 4.46 Multiple comparisons between the expected and observed process time differences for phases

			Phase 2	Phase 4	Phase 3
		mean	7.219	7.625	7.742
	mean				
Phase 1	3.938		3.281*	3.688*	3.804*
Phase 2	7.219			0.406	0.523
Phase 4	7.625				0.117

*p < 0.05

4.9 Summary of Results

The purpose of this study was to determine if tutoring could be enhanced through computer-mediated communication (technology) and feedback cues. The four communication media included collocated communication, email, a chatroom, and video teleconferencing. Subjects used each communication medium twice – once with access to a feedback cue and once without access to a feedback cue. The tutor led subjects through a four-phase problem solving method to develop solutions for eight math problems. Each subject completed each math problem using a different experimental method. Data was collected for each phase and for the overall process. The results of the data analysis for the dependent variables analyzed for all phases are shown in Table 4.47. Table 4.48 summarized the multiple comparisons of the significant technology effects and Table 4.49 summarizes the multiple comparisons of the significant phase effects. The results for the dependent variables analyzed for the overall process are reported in Table 4.50. The multiple comparison summaries for technology are shown in Table 4.51. Table 4.52 contains the results for the ranked variables. Table 4.53 contains the summary of the multiple comparisons of the significant technology satisfaction ranks and Table 4.54 contains the summary of the multiple comparisons of the significant feedback cue satisfaction ranks.

Table 4.47 Summary of the analysis of dependent variables analyzed by phase

	Feedback Cue	Technology	Phase	Feedback x Technology	Feedback x Phase	Technology x Phase	Feedback x Technology x Phase
	p-value	p-value	p-value	p-value	p-value	p-value	p-value
Process Time	0.238	<0.001*	<0.001*	0.941	0.418	0.910	0.973
MANOVA	0.085	0.246	<0.001*	0.664	0.419	0.009*	0.196
Accuracy	0.053	0.001*	0.271	0.525	0.992	0.073	0.886
Perceived Accuracy	0.213	0.093	0.044*	0.626	0.845	0.116	0.033*
Perceived Understanding	0.307	0.170	0.002*	0.468	0.241	0.004*	0.152
MANOVA	0.382	0.006*	0.415	0.250	0.675	0.764	0.141
Satisfaction	0.106	0.005*	0.776	0.089	0.917	0.328	0.104
Ease of Use	0.386	0.005*	0.707	0.224	0.358	0.448	0.227
Efficiency	0.286	0.001*	0.462	0.400	0.881	0.391	0.088
Effectiveness	0.949	0.022*	0.425	0.208	0.323	0.196	0.081

*p < 0.05

Table 4.48 Summary of the mean comparisons by technology for all phases

Variable	Technology	Email	Chatroom	Video Teleconferencing
Time				
	Collocated	*	*	>0.05
	Email		>0.05	*
	Chatroom			>0.05
Satisfaction Response				
	Collocated	*	*	*
	Email		*	*
	Chatroom			*
Ease of Use Response				
	Collocated	*	*	*
	Email		*	*
	Chatroom			*
Efficiency Response				
	Collocated	*	*	*
	Email		*	*
	Chatroom			>0.05
Effectiveness Response				
	Collocated	*	*	*
	Email		*	*
	Chatroom			>0.05

*p < 0.05

Table 4.49 Summary of the mean comparisons by phase

Variable	Phase	Phase 2	Phase 3	Phase 4
Accuracy				
	Phase 1	>0.05	*	>0.05
	Phase 2		>0.05	*
	Phase 3			*
Perceived Accuracy				
	Phase 1	>0.05	>0.05	*
	Phase 2		>0.05	*
	Phase 3			*
Subjects' Perceived Understanding				
	Phase 1	>0.05	>0.05	*
	Phase 2		>0.05	*
	Phase 3			*
Time				
	Phase 1	*	*	*
	Phase 2		>0.05	*
	Phase 3			>0.05

*p < 0.05

Table 4.50 Summary of the analysis of dependent variables analyzed for the overall process

	Feedback Cue p-value	Technology p-value	Feedback x Technology p-value
MANOVA - Accuracy	0.384	0.018*	0.816
Accuracy	0.053	0.271	0.525
Perceived Accuracy	0.149	0.026*	0.164
Perceived Understanding	0.836	0.013*	0.658
Tutor's Perceived Understanding	0.405	0.033*	0.921
Process Time	0.423	<0.001*	0.202
MANOVA - User Satisfaction Responses	0.368	0.024*	0.587
Satisfaction	0.291	0.001*	0.237
Ease of Use	0.741	0.010*	0.554
Efficiency	1.000	0.003*	0.227
Effectiveness	0.689	0.013*	0.194

*p < 0.05

Table 4.51 Summary of the mean comparisons by technology for overall process

Variable	Technology	Email	Chatroom	Video Teleconferencing
Accuracy Response				
	Collocated	*	*	>0.05
	Email		*	*
	Chatroom			>0.05
Subjects' Understanding Response				
	Collocated	*	>0.05	>0.05
	Email		*	>0.05
	Chatroom			>0.05
Tutor's Understanding Response				
	Collocated	*	>0.05	>0.05
	Email		*	*
	Chatroom			>0.05
Time				
	Collocated	*	*	>0.05
	Email		>0.05	*
	Chatroom			*
Satisfaction Response				
	Collocated	*	>0.05	*
	Email		*	*
	Chatroom			>0.05
Ease of Use Response				
	Collocated	*	>0.05	*
	Email		*	>0.05
	Chatroom			>0.05
Efficiency				
	Collocated	*	*	*
	Email		*	*
	Chatroom			>0.05
Effectiveness				
	Collocated	*	*	*
	Email		*	>0.05
	Chatroom			>0.05

*$p < 0.05$

Table 4.52 Summary of the analysis of dependent ranked variables

Variable	Test Statistic	Phase 1 p-value	Phase 2 p-value	Phase 3 p-value	Phase 4 p-value	Overall p-value
User Satisfaction						
Technology	S	0.030*	0.010*	0.001*	0.001*	0.003*
Feedback Cue	S	0.034*	0.034*	0.034*	0.034*	0.059
Technology x Feedback Cue	F	0.339	0.279	0.683	0.316	0.298
Ease of Use						
Technology	S	0.003*	0.005*	0.032*	0.002*	0.004*
Feedback Cue	S	0.034*	0.034*	0.034*	0.034*	0.034*
Technology x Feedback Cue	F	0.186	0.600	0.224	0.709	0.014*
Efficiency						
Technology	S	0.001*	0.001*	0.001*	0.001*	0.003*
Feedback Cue	S	0.034*	0.034*	0.034*	0.034*	0.034*
Technology x Feedback Cue	F	0.177	0.177	0.060	0.751	0.228
Effectiveness						
Technology	S	<0.001*	0.001*	0.001*	0.007*	0.005*
Feedback Cue	S	0.034*	0.034*	0.034*	0.034*	0.034*
Technology x Feedback Cue	F	0.363	0.233	0.016*	0.412	0.154
Comfort						
Technology	S	0.001*	0.004*	0.005*	0.010*	0.003*
Feedback Cue	S	0.034*	0.034*	0.034*	0.034*	0.034*
Technology x Feedback Cue	F	0.378	0.151	0.412	0.633	0.271

*p < 0.05

Table 4.53 Summary of multiple comparisons of the significant technology ranked variables

Variable	Technology	Email	Chatroom	Video Teleconferencing
Phase 1 Satisfaction				
	Collocated	**	>0.05	*
	Email		*	>0.05
	Chatroom			>0.05
Phase 2 Satisfaction				
	Collocated	**	>0.05	*
	Email		**	>0.05
	Chatroom			>0.05
Phase 3 Satisfaction				
	Collocated	**	>0.05	**
	Email		**	>0.05
	Chatroom			*
Phase 4 Satisfaction				
	Collocated	**	>0.05	**
	Email		**	>0.05
	Chatroom			>0.05
Overall Satisfaction				
	Collocated	**	>0.05	>0.05
	Email		**	>0.05
	Chatroom			>0.05

*p < 0.05
**p < 0.01

Table 4.54 Summary of multiple comparisons of the significant feedback cue ranked variables

Variable		Feedback Cue
Phase 1 Satisfaction	No Cue	*
Phase 2 Satisfaction	No Cue	*
Phase 3 Satisfaction	No Cue	*
Phase 4 Satisfaction	No Cue	*
Overall Satisfaction	No Cue	>0.05

*$p < 0.05$

Chapter 5 Discussion

5.1 Experimental Process Issues

The purpose of this study was to determine if tutoring could be enhanced through computer-mediated communication and a feedback learning cue. The four communication media consisted of collocated communication, email, a chatroom, and video teleconferencing. Email and chatroom were text-based; however, email was an asynchronous communication method and the chatroom was synchronous. Video teleconferencing and collocated communication had both audio and video channels for communication in addition to a text channel. Subjects used each communication medium twice – once with access to a feedback cue and once without access to a feedback cue. Subjects used to the feedback cue to represent their level of understanding with the math problem: low, medium, or high understanding. A tutor led the subjects through a four-phased problem solving method to solve eight math problems. The four-phase problem solving approach was used to determine if the different phases required different levels of technology and feedback cues. Each subject completed each math problem using a different experimental medium.

Sixty-four trials were conducted with eight subjects in the Usability Methods Research Laboratory located in McBryde Hall, a National Science Foundation funded research laboratory jointly operated by Computer Science and Industrial and Systems Engineering faculty at Virginia Tech. This research was conducted from the beginning of July through the beginning of August 1997. As mentioned before, each trial was comprised of four phases. All data collected in Phases 1 and 2 were usable. However, during Phase 3, two different subjects abandoned determining a solution and requested the tutor to take him or her through the solution, Phase 4. Because the subject did not obtain a solution, the task for Phase 3 was considered incomplete. The subject completed the questionnaire for Phase 3 and then the tutor led the subject through the entire solution (Phase 4). Phase 3 was not completed for email without a feedback cue (task five) and video teleconferencing with a feedback cue (task eight). Subjects ran out of time (three times it was the same subject), in the fourth phase of eight trials. These trials included email without a feedback cue (tasks three and five), email with a feedback cue (tasks one and four), video teleconferencing without a feedback cue (tasks four and eight), and chat with a feedback cue (tasks four and eight). Overall, there were nine trials with incomplete data.

Some unusual events occurred during this study. The Director of ASPIRE '97 asked one of the subjects to leave the ASPIRE program due to inappropriate behavior. This subject was asked to leave the Friday before the last week of trials. The Director agreed to let this subject participate in the last trial late Thursday night. Another subject participated in the chatroom with a feedback cue and video teleconferencing without a feedback cue without eyeglasses, which the subject needed to see the computer screen. In the final chatroom trial, one subject occasionally fell asleep during Phase 4.

The research questions and hypotheses in this study were developed based on a review of the literature. The majority of the literature covered group support systems (GSS) and computer supported cooperative work (CSCW). Due to the limited number of subjects who were able to participate in this research, this research did not address group processes. However, the researcher believed results from previous group studies would still be applicable to this study.

5.2 Problem Solving Phase

The problem solving phase significantly affected accuracy. These results supported the problem solving method implemented for tutoring. The accuracy in Phase 4 was significantly higher than the accuracy in Phases 2 and 3. In Phase 2, the subject planned their approach. As long as subjects believed their plan was correct, they could continue to the next phase without having asked the tutor a single question. In Phase 3, mistakes made in Phase 2 would carry over. The difference between performance in Phases 2 and 3 was not significant. However, in Phase 4, the tutor took an active role in the problem solving process. He led subjects back through their problems, starting with Phase 1. They worked together to determine if the subject solved the problem correctly. Performance in Phase 1 was significantly higher than performance in Phase 3. Again, this might be attributed to the process. In Phase 1, the subject defined the problem's requirements. At this point, the subject only needed to know the expectations of the problem, not how to solve the problem. In Phase 3, the subject actually solved the problem. Therefore, any errors made in previous phases had the potential to carry over.

In the analysis of perceived accuracy and understanding, phase was also significant. Subjects had the highest perceived accuracy and level of understanding in Phase 4. Again these results can be attributed to the problem solving process. In Phase 4, the tutor led the subject back through the problem. Therefore, by the conclusion of Phase 4, the subject should have completely understood the solution. In theory, the tutor did not allow subject to end the tutoring session if the subject admitted he or she did not understand the problem. However, in this study, time constraints might have ended the session prematurely.

From the analysis of process time, phase was significant. The mean time to complete Phase 1 was significantly lower than the mean time to complete the other three phases. In addition, the time to complete Phase 4 was significantly longer than the time to complete Phase 2. Based on the problem solving process, Phase 1 was not expected to require as much time as the other phases (Table A.2 in Appendix A.2). The task involved with Phase 1 was reading comprehension. The problem statements were fairly short with little complexity. Phase 2 involved recalling or looking up equations and determining the steps required for solving the problem. Phase 3 required mathematical substitution and simplification, which in some cases involved many steps. And in Phase 4, the tutor led the subject back through all of the previous steps to determine if the solution was correct. Phases 2, 3, and 4 involved activities that required more time than the reading comprehension required in Phase 1. The difference between Phase 2 and Phase 4's process time was not expected. The time difference between Phases 2 and 4 indicated subjects spent more time reviewing the solution with the tutor than planning their approach to the problem. However, when the expected time differences between phases were filtered out, the difference between Phases 2 and 4 were not significant. This result indicated the subjects were spending the expected amount of time in each of these phases. The results of the analysis on expected times also indicated subjects were not spending as much time as expected in Phase 1. The key to Phase 1 was for subjects to gain an understanding of the problem's expectations. Errors in subsequent phases might have been caused by a poor interpretation of the problem statement. For example, in problem number 7, subjects were given the method to partially verify an equation. Several subjects indicated they were to use two equations to completely verify the equation. This error in Phase 1 had numerous impacts. The math expert subtracted 2 points from the Phase 1 score for this error. In addition, the process time increased because completely verifying the problem required many mathematical steps.

The impact of phase alone on the dependent measures was not of major importance. The impact of phase in determining which communication media and feedback cue level should be used in the tutoring process was the important issue. Generally, the phase was not important in determining the communication media and feedback cue level to be used in the tutoring process based on the analysis of the interaction

between phase and technology level, the interaction between phase and feedback cue level, and the interaction between phase, technology, and feedback cue level. These interactions were not significant based on the analysis of accuracy, process time, and user satisfaction. The problem solving process might have provided too much structure for the math problems. Had the math problems been more complex, the problem-solving phase might have been important in determining which communication media and feedback cue level can be used for tutoring. However, due to the time limit imposed, the problems were not complex.

The analysis of the perceived understanding was one exception to the lack of significance for the interaction between phase and communication media. This result was interesting. The mean perceived understanding using collocated communication, the chatroom, and video teleconferencing was significantly higher during Phase 4 than in the other phases. However, for email the highest response was during Phase 1 although the difference between phases was not significant. In Phase 1, 2, and 3, the difference in understanding was not significant between the communication conditions. These results indicated that in Phase 4, collocated communication, chatroom, and video teleconferencing all helped the subject perceived a higher level of understanding than email. Phase 4 forced the subject to interact with the tutor. The discussion could get complex in all communication modes. However, when the solutions were incorrect, trying to determine if errors were attributed to calculations or conceptual breakdowns was especially difficult in the text-based modes. The difference between understanding might be explained by the communication mode. Collocated communication, the chatroom, and video teleconferencing were synchronous communication modes which email was an asynchronous communication mode. Because the goal of tutoring was learning, understanding was a key outcome in tutoring. The presence of feedback aided the subjects' evaluation of their learning process (Ashford and Cummings, 1983). Email was a lean communication mode; therefore, the feedback was not only slow, it lacked cues. With the chatroom, even though the subjects were deprived of cues, the feedback was fairly rapid. In addition, subjects had access to other chatroom users' messages from which they might have learned the information from a different perspective. In video teleconferencing and collocated communication, the tutor saw the subjects' reactions to the tutoring process in Phase 4. When the subject looked confused the tutor could immediately find out what was wrong.

5.3 Technology Level

In the literature, task performance was generally better for groups supported by GSS as opposed to collocated groups (McLeod, 1992; Ellis and Jarvenpaa, 1989; Smith and Vanecek, 1989; Gallupe and DeSanctis, 1988; Turnoff et al., 1982). In studies by Easton (1989) and Chidambara and Jones (1993), the quality of the decision did not improve while other measures of performance did improve through the use of GSS. However, in studies focused on CSCW, as opposed to GSS, there was no difference in the task quality and/or accuracy between collocated and computer-mediated communication (Kies, Williges, and Rosson, 1997; McCarthy and Monk, 1994; Kinney et al., 1994; Hiltz, Johnson, and Turoff, 1986; Burke and Chidambaram, 1994; Smith et al., 1989). One difference between these two groups of studies was that the GSS literature focused on decision making while the computer-mediated communication literature focused on collaboration. The results of this study supported the latter set of studies; the technology level did not significantly affect accuracy.

From a multivariate analysis of variance on accuracy and the accuracy perceptions, there was a significant relationship for technology. The accuracy was similar in all communication conditions based on the analysis by phase and the analysis for the overall process. This result suggested subjects could have used any computer-mediated communication method without affecting the math problem's accuracy. This

study was changed from group to one-on-one tutoring which might explain the lack of difference. The tutor and subjects did not have to manage and process information from multiple people in the video teleconferencing and email conditions. While subjects had the ability to view all participants' conversations in the chatroom, the participants did not work together on problems. The time constraint may have also influenced the accuracy results. If a subject ran out of time and did not finish the review, the trial ended before the subject completely understood the process required to solve the problem. The data was analyzed both including and excluding the incomplete data point. However, had the subject had a sufficient amount of time, the Phase 4 and overall results might have been affected.

Subjects' perceptions of the overall accuracy of their work and their overall understanding of the work they accomplished were affected by technology. Through further analysis of the perceived overall accuracy, email was the condition in which the subjects had the least confidence in the accuracy of their work. In addition, the perceived overall accuracy was lower in the chatroom compared to collocated communication. These results were logical. When subjects used email, the communication process was, as many subjects phrased it, slow and tedious (Appendix A.27 and A.28). Email was a lean communication medium; nonverbal cues were eliminated and feedback between the tutor and subject was not immediate. Therefore, they had to rely on the email messages to convey all of the information and they had to rely on their own perceptions of how they were performing. In collocated communication and video teleconferencing, subjects had more channels of communication in addition to nonverbal cues; in collocated communication, video teleconferencing, and the chatroom, feedback was more immediate than email. Collocated, they saw the tutor's facial expressions and body gestures and heard the vocal tone and inflections. These were good indicators from which to judge performance. These forms of cues were also present in the video teleconferencing conditions. In the chatroom, cues were of a different nature. Multiple participants were working in the chatroom at one time. Therefore, the subject could judge his or her performance against the performance of the other participants. Then, based on the tutors written comments, the subject had a frame of reference in which to judge his or her own work (Appendix A.29).

Overall, the subjects had trouble understanding what they had done when they used email compared to when they were either collocated or used the chatroom. Again, this might be explained due to the leanness of email. The overall tutoring process was moderately equivocal, especially when the subject did not understand a concept. Therefore, email might not have been a sufficiently rich medium for the purpose of tutoring. Another interesting aspect of this result was that the overall understanding was not significantly different between video teleconferencing, the chatroom, and collocated communication and there was no difference between video teleconferencing and email. The literature suggested that video teleconferencing was a rich medium with a high level of social presence. Therefore, differences were not expected between collocated and video teleconferencing. The result that there was no difference in the perceived understanding between email and video teleconferencing suggested another factor influenced the subjects' perceptions. Research was conducted on the optimal frame rate and resolution for videoconferencing (Kies, Williges, and Rosson, 1997; Masoodian, Apperley, and Fredrickson, 1995). Some of the research showed that for frame rates less than 5 fps, the video quality was not acceptable (Masoodian, et al., 1995). Kies (1997) found that while the frame rate did not significantly affect performance, subjective evaluations were affected. Specifically, Kies found than frame rates less than 6 fps and resolutions less than 320x240 should be avoided and high-quality audio was important. Other research supported the importance of audio in video teleconferencing (Ochsman et al., 1974). The quality of the audio was probably a key to the lack of difference between overall understanding perceptions in video teleconferencing and email. While the frame rates were not specifically measured, the researcher did not notice frame rates less than 9 fps. The majority of the comments from both subjects and tutor were complaints about the quality of the audio channel.

In the literature, process time was a frequent outcome variable. Process time was significantly longer in text-based computer-mediated environments compared to collocated environments in both the GSS and CSCW literature (Kinney et al., 1994; Zack, 1994; McLeod, 1992; Pinsonneault and Kraemer, 1990; Hiltz et al., 1986; Siegel, Dubrovsky, Kielser, and McGuire, 1986; Weeks and Chapanis, 1976). Many of the researchers attributed the longer times to the time required to enter text and to time lags in communication. In addition, Fowler and Wackerbarth (1980) demonstrated decision time increased as the number of cues decreased. Furthermore, Siegel (1986) found groups communicating face-to-face had faster process times and had more comments than groups using electronic mail. However, the process time for video conferencing was not found to be significantly different from collocated communication (Ochsman and Chapanis, 1974; Weeks et al., 1976; Kinney et al., 1994). In addition, audio channels significantly reduced process time compared to text-based communication for problem solving tasks (Ochsman et al., 1974). These results were somewhat supported by this study.

In the analysis for all phases and the overall analysis, the communication media (technology) significantly affected process time. The audio-visually linked communication modes' process times were significantly faster than the email process time. There was no difference in the process times between the text-based modes. And the audio-visually linked communication modes did not have significantly different process times. For the overall process, the audio-visually linked modes were also significantly faster than the chatroom.

From the literature, the results for video teleconferencing and collocated communication were supported. In both communication modes, the subject and tutor could verbalize what they were thinking. The main difference between the two modes was that the tutor could not see the subject's work over the video teleconferencing system. The problem was the contrast between the paper and the pencil lead was poor so the image transmitted resembled a blank piece of paper. However, both the tutor and subjects learned to verbalize and use hand gestures to describe the information and figures associated with the math problem. Walther (1992) acknowledged that people looked for ways to overcome problems caused by the communication medium. An increased resolution or the use of whiteboards might also eliminate this problem (Kies et al., 1997). Increased resolution would pick up more details in the video channel. A whiteboard would allow all users to enter text from the keyboard and/or use the mouse to draw shapes on a computer screen that could be simultaneously edited by everyone with access to the whiteboard.

Email inherently had a time lag because it was an asynchronous communication method. Even when the tutor responded immediately to the subject, the subject might have been involved in the problem and forgot to look at incoming messages. Typing was also a slower form of communication than speech (Hiltz et al, 1986). In addition, the reduced number of cues had been shown to increase the time to communicate textually (Kinney et al., 1994; Fowler et al., 1980). Therefore, the results for the overall process were supported in the literature.

Research showed that time lags in communication caused frustration (Smith et al., 1989). From the GSS literature, groups that used GSS had lower satisfaction than collocated groups (McLeod, 1992). Significant differences between satisfaction with technology levels were hypothesized. Recall, the subjective variables (satisfaction, ease of use, efficiency, and effectiveness) were measured using two methods, by rank ordering the communication media and using a Likert-type rating scale. In the analysis of the satisfaction ranks, technology significantly affected satisfaction in all phases and overall. In Phases 1, 2, 4,and overall, subjects were significantly more satisfied in collocated communication compared to video conferencing and email. Differences between collocated communication and email were expected. However, the difference between collocated communication and video teleconferencing was not expected. The subjects' comments supported the lack of satisfaction with both email and video teleconferencing.

Most of the comments about email were related to a lack of feedback immediacy. In addition, one subject noted email was impersonal which was related to both social presence and media richness theory. Email eliminated cues. According to media richness theory, the communication medium must match the task. Phases 1, 2, 4, and the overall tutoring process might be considered to be moderately equivocal. Each of these phases and the overall tutoring process required concepts that might have been ambiguous to the subjects. Therefore, this result generally supported the media richness theory. In video teleconferencing, the lack of satisfaction might be attributed to two concepts. First, video teleconferencing might have been too rich and provided too much social presence for tutoring. This idea was supported by a subject who said they could not change facial expressions without having the tutor interrupt to ask what was wrong. In addition, subjects would move in and out view depending on whether they were working on the problem or trying to communicate. Unfortunately, data was not collected to determine if this action was intentional. Second, the technology used for video teleconferencing did not support high quality audio. Several studied indicated audio, not video, was key to the communication process (Sellen, 1995; Ochsman et al., 1974). Kies (1997) found degraded audio quality negatively affected users' perceptions. Many subjects complained that video teleconferencing was hard to use because of the low quality audio (Appendix A.27 and A.28). Both the subjects and the tutor had to repeat themselves, which was a redundancy of effort. Subjects were also more satisfied in the chatroom compared to email. Many subjects referred to an immediacy of feedback as a difference between the chatroom and email. Therefore, even though nonverbal cues were eliminated, the chatroom was a media with more social presence and was a richer medium than email. The subjective variable ranks, which were strongly correlated, generally supported the results from analysis of the satisfaction ranks.

During Phase 3, subjects were more satisfied in both collocated communication and the chatroom compared to either video teleconferencing or email. The difference between collocated communication and email was expected. Similarly, the difference between email and chatroom was anticipated, because the chatroom was synchronous (not in a strict sense, in that the enter key had to be pressed for the message to transmit, but entered text immediately appeared in the chatroom message window). However, the difference between video teleconferencing and the chatroom was not expected. In Phase 3, the subject solved the problem. In the chatroom condition, multiple participants communicated with the tutor. Although, subjects benefited from seeing everyone's questions, approaches, and sometimes answers, the chatroom was a relatively lean communication medium compared to video teleconferencing. However, in video teleconferencing, the subjects completed their work in front of a camera. Media richness theory suggested that the communication medium should match the task equivocality (Daft et al., 1984; Walther, 1992). The equation simplifications and mathematical substitutions were concrete and unambiguous tasks. Therefore, video teleconferencing may have provided too many communication channels and cues thus negatively impacting satisfaction. The immediacy of the feedback in the chatroom on the other hand might have provided a sufficient number of cues and immediate feedback for the subjects to complete Phase 3. One subject commented that he could not make a face without the tutor asking what was wrong when he used video teleconferencing (Appendix A.28). This comment supported the idea that too much information was being shared with video teleconferencing. Another subject would even move away from the camera while he was thinking and then return to the camera to talk to the tutor.

Media richness theory, as mentioned earlier, suggested the media should match the task's equivocality, which was heavily debated (Walther, 1992). The results of several studies contradicted media richness theory (Walther, 1992; Kinney et al., 1994). The contradicting research reviewed suggested differences might be caused by the research was conducted in the field, subjects had well-established relationships, and/or the studies took place over a relatively long period of time. Waskul and Douglass (1997) suggested individuals learned to adapt to the computer environment and therefore will learn to overcome obstacles caused by lean communication media. While this study mildly supported the media

richness and social presence theory, there was some evidence that subjects were learning to adapt to their environment. In video teleconferencing, the tutor and subjects would use hand motions to aid their explanations because the video resolution was not high enough for pencil drawings. With the text-based media, the tutor and subjects occasionally used text to express feelings typically communicated through facial expressions and gestures or vocal tones. The tutor frequently used capital letters to capture the subject's attention. One subject interpreted the use of capital letters to be yelling and told the tutor to stop yelling. Some subjects used ":)" (smiley faces) when they understood a concept or correctly solved the problem. These textual feelings are referred to as emoticons, which are symbols developed by users to overcome difficulties associated with textual communication (Waskul et al., 1997).

From the analysis of the satisfaction response, each technology level was significantly difference from every other technology level. Subjects were most satisfied with collocated communication followed by the chatroom, video teleconferencing, and email. From the analysis of the overall tutoring process, email had the lowest satisfaction response. In addition, satisfaction was higher with collocated communication compared to video teleconferencing. The high level of satisfaction in collocated communication could be explained. Subjects were accustomed to face-to-face communication. In addition, feedback was immediate and it was rich in cues. The subjects' comments taken after each trial supported the satisfaction response. Subjects said collocated communication was direct, personal, fast, and easy to use. However, there was one comment that indicated the social presence was too high for the purpose of tutoring. The subject pointed out that "it [was] hard to concentrate on the problem when someone [was] staring down your throat" (Appendix A.27). The richness and social presence of the chatroom appeared to be well matched to tutoring. While in the analysis by phase the chatroom was not the medium with the highest satisfaction, there was no difference between collocated communication and the chatroom in the overall analysis. Subjects were actively engaged in text-based conversations in the chatroom. Many subjects said the chatroom was fast and easy; although, one subject indicated he felt he was "under pressure to answer faster" (Appendix A.27). Other problems that occurred in the chatroom included difficulty talking about diagrams and entering mathematical equations and confusion if they had not been paying attention to the chat screen (Appendix A.27). Video teleconferencing comments indicated the technology made the communication difficult. The audio quality was poor. Both the subjects and tutor frequently repeated themselves to be understood. This redundancy of effort might have influenced their perceptions. Even though the chatroom eliminated cues, the interface's ease of use may have attributed to subjects' satisfaction level. In addition, feedback to the subject was immediate. Because the subjects complained about the audio, the researcher was surprised that most subjects did not take advantage of the chatroom capabilities of the video teleconferencing software. As discussed previously, based on the subjects' comments, slow feedback appeared to negatively influence the subjects' perceived satisfaction.

5.4 Feedback Cue Level

The feedback cue served two purposes: subjects could inform the tutor when they were having trouble in a non-threatening manner and it was a supplemental form of feedback to the tutor about the subjects' understanding of the concepts. The concept of giving and receiving feedback could be intimidating (Ashford and Cummings, 1983). However, students giving and receiving feedback was key in the learning process (McKendree, 1990). Feedback was also a form of evaluation (Ashford et al., 1983). Therefore, through the feedback cue, the subjects should have continuously re-evaluated their performance. In addition, the presence or lack of cues was a prominent theme in the research of communication media (Short et al, 1974; Daft et al., 1984; Walther, 1992; Kinney et al., 1994; Zack, 1994). The feedback cue conveyed immediate and continuous information back to the tutor. This was supposed to allow the tutor to know exactly how well the subject understood the problem.

In the analysis of accuracy and process time, the feedback cue was not significant. Accuracy, perceived accuracy, perceived understanding, and process time were similar regardless of the feedback cue. One explanation for the feedback cue's lack of significance might be that the subjects did not use the feedback cue. The lack of use of the feedback cue was evidenced by the low number of times the subject used the feedback cue documented during each trial (Appendix A.30). Most subjects admitted they forgot to use the cue (Appendix A.27 and A.28). This difficulty might have been caused by a poor interface design. Subjects frequently described the feedback cue as slow and tedious (Appendix A.27 and Appendix A.28). Some of the subjects suggested they might have used the feedback cue more frequently had it been part of the computer interface (Appendix A.28).

Another explanation for the lack of feedback cue use presented itself in subject's comment that "constantly stopping what I'm doing to think of how I'm doing disrupts my flow." (Appendix A.28) The subject was correct; "focusing attention actually requires a measurable amount of time" and is a function of the task difficulty and what the person was doing prior to when he changed his attention (Glass Holyoak, and Santa, 1979; p.195). In this study, the task was mildly difficult. The problem had a well-defined goal with some of the required information provided. However, the subject had to recall or look up the equations and determine the process to use to actually obtain a solution. Subjects also had to monitor the tutoring process. Using the feedback cue was a skill that had to be learned. With practice, the performance of motor skills was perfected (Glass et al. 1979). Until the skill was innate, performing the skill was a distraction.

Individuals tend to focus on important activities and ignore everything else (Glass, et al., 1979). Because the environment was complicated the subjects probably filtered out the feedback cue as unimportant. The math problem was important because the subjects' goal was to understand the concepts and solve the problem; the communication media was important because it mediated the communication process between the subject and the tutor. These were two key aspects that the subject could not ignore. The feedback cue, while helpful to the tutor was not essential and this might provide another explanation as to why subjects did not use it.

The feedback cue was a non-threatening method for the subject to provide the tutor with feedback on his or her level of understanding. Because subjects did not have to vocalize if they were unsure, hopefully the subjects would be more comfortable while they worked with the tutor. Unfortunately, the subjects found the feedback cue "intrusive" (Appendix A.29 and A.30). In all phases, subjects were more satisfied in conditions without access to the feedback cue compared with conditions with access to the feedback cue. In all phases, the subjective ranks, ease of use, efficiency, effectiveness, and comfort, supported the differences in satisfaction with the feedback cue. Surprisingly, based on the results in the phases, the overall satisfaction was similar in conditions with and without the feedback cue. The results from the analysis of the overall efficiency, effectiveness, ease of use, and comfort contradicted the subjects' overall satisfaction results.

While many of the subjects had negative comments regarding the feedback cue, some of the comments were positive. One subject recognized the tutor did not bother him with questions about how he was doing when he used the feedback cue (Appendix A.27). Several subjects commented the feedback cue was helpful but did not elaborate.

Negative perceptions about the feedback cue might have resulted from the interface design. Originally, the researcher intended to make the feedback cue part of the computer interface. However, due to time limitations and programming complications, the feedback cue was designed as a separate piece of

hardware. Many subject comments supported the subjects would have had more favorable attitudes towards the feedback cue if the cue had been part of the computer interface (Appendix A.27 and A.28).

Subjects' perceptions about the feedback cue might have been more positive if the tutor used a feedback cue similar to the subjects' feedback cue. In this feedback cue, the tutor would convey his perception of the subject's accuracy. If the subjects received feedback, they might have been more motivated to use their own feedback cue. The subjects would have directly perceived the benefits of sending and receiving feedback. In addition there would have been a mechanism in place for the subject to immediately receive feedback, which may have helped in email tutoring.

The feedback cues may have been more satisfying for group tutoring. Several subjects commented that in the chatroom, the feedback cue was better for helping the tutor keep track of everyone's progress. In the chatroom, multiple subjects commanded a single tutor's attention. The tutor used the feedback cue to evaluate who needed the most help (Appendix A.29). Then, the tutor focused his attention to a subset of the subjects in the chatroom. Therefore, the tutor used the feedback cue as an evaluation tool (McKendree, 1990).

5.5 Interaction between Technology Level and Feedback Cue Level

The interaction between feedback cue and technology was where differences in the dependent variables were expected. Significant effects were expected in accuracy, process time, and satisfaction. As a form of supplemental information, the feedback cue should have been important in text-based communication because the feedback cue provided instant and constant information to the tutor (Daft et. al., 1984, 1986; Kinney et al., 1994). While in collocation communication and video teleconferencing, the feedback cues might have provided redundant information and therefore would not affect the results. When the tutor could not see the subject's face or see the work to assess the subject's progress, the feedback cues should have been more effective. In addition, when the subjects used email, relatively long periods of time elapsed between messages. During these lapses, the tutor did not know how the subject was progressing unless the feedback cue was used. During several trials, the tutor sent messages asking how the subject was doing. Occasionally, the subject got angry for the interruption and ignored the message; the tutor was left to wonder how the subject was doing.

Again, the feedback cues lack of use might be a contributing factor. Subjects complained the feedback cue was tedious and slow. In addition, thinking about how well the problem was understood took time. These comments suggested two problems. First the feedback cue design was poor as mentioned earlier. Second, the mental workload caused by the feedback cue in addition to the problem solving task and the communication process might have been a mental overload. Therefore, the subject might have opted to ignore the feedback cue in favor of focusing on the task and the communication process. Collocated, the subject vocally or visually indicated to the tutor whether or not they understood the problem and related concepts. However, in the computer-mediated modes, the attention was divided between the math problem and the communication process. The reason the communication process was an issue is that speech is an innate skill for most people (Glass et al., 1979). However, using the computer to mediate communication had to be learned. This involved using a mouse, keyboard, and monitor. Similarly, the subjects had to learn to manipulate the feedback cue to reflect their level of understanding. With the amount of mental workload, only extreme variations in understanding may have been sensed by the subject (Glass et al., 1979). Therefore, the differences in three-levels of understanding might have been too refined for the subjects to discern. A two-level feedback cue: high and low understanding, might have been a more appropriate design.

In collocated communication, the subject and the tutor could gather nonverbal cues from each other directly. Posture, tone of voice, and facial expression quickly convey the subjects' understanding. In the collocated condition, subjects did not understand the point of the feedback cue, which was logical because the feedback provided redundant information to the tutor. During email, subjects had to send and check messages. The feedback cue added another source of distraction. In the chatroom subjects remarked the feedback cue was helpful because of the additional students involved. The tutor could focus his attention on students with a medium or low level of understanding. And in video teleconferencing, the tutor and subjects sometimes had difficulty understanding each other.

5.6 Tutor's Perceptions

The tutor responded to questions after each trial was complete. In addition, after all of the trials were complete, he rank ordered the experimental conditions based on his satisfaction, ease of use, effectiveness, and efficiency. The tutor's perceptions were important because he was a member of the tutoring system. In addition, if the tutor's perceptions matched the subject's it would be a form of validation.

5.6.1 Perceptions of Subject Understanding

After each trial the tutor responded to a question about his perception of the subject's understanding. The tutor perceived the subjects understood the overall problem the least when they used email. This result supported the subjects' response. The subjects perceived their own understanding and accuracy to be the lowest when they used email. These results were encouraging because it was an indication that the tutor and subject tended to agree on their perceptions of the subject's performance. In transferring this idea to an actual tutoring environment, ideally, if the tutor recognized a student did not have an understanding of the material, the session would not end until understanding had been achieved.

5.6.2 Tutor Satisfaction

The tutor's perceptions were strongly correlated; therefore, efficiency, effectiveness, and ease of use generally supported his perceived satisfaction. The tutor ranked the communication media in the following order from most to least satisfying: collocated communication, video teleconferencing, the chatroom, and email. The tutor described collocated communication as the most convenient communication mode. His description of email clearly expressed his dissatisfaction (Appendix A.29). The tutor frequently commented that the email condition was too slow for tutoring. These comments were similar to the subjects' comments (Appendix A.27 and A.28). The tutor commented video teleconferencing was great when everything worked; he was referring to the poor audio quality. He also liked the chatroom; however, he was concerned some subjects did not use it correctly.

From the satisfaction response after each trial, the tutor was least satisfied when he used email. This result was reflected in the tutor's satisfaction ranked order. The tutor was also more satisfied using collocated communication compared to video teleconferencing. However, there was no difference in satisfaction between collocated communication and the chatroom. This discrepancy might result from the frame of reference. The ranks imposed an order while the responses did not.

The tutor was more satisfied when the subjects had access to feedback cues compared to when they did not have access to feedback cues. The feedback cues provided him with additional information that he could use to help the student. The subjects did not see the feedback cues in the same way; they felt the

feedback cues were a nuisance. For the tutor, the feedback cue did not provide the distraction to the tutoring process like it did for the subjects. The tutor only had to visually check the feedback cue lights to determine the subjects' understanding. In addition, he was not working out the problem with the subject because he already knew how to solve the problem. And the feedback cue helped the tutor to change his level of focus on the tutoring process. When the subject had a high level of understanding, the subject did not need detailed input from the tutor. However, if the subject had a low level of understanding, the tutor needed determine what the subject did not understand and how to explain the problem to the subject. Again, the tutor's preferences for the feedback cue did not match the subjects' preference for no feedback cue. Had the subjects directly benefited from the immediacy of feedback, which the feedback cue provided, the subjects' satisfaction with feedback cue might have higher.

5.7 Analysis of the Process Effects

The process was analyzed for time and accuracy to determine if there was a significant ordering effect. Subjects received the math problems in the same order. In Phase 3, two subjects asked to continue to Phase 4 without obtaining a solution in Phase 3. In addition in Phase 4, eight subjects ran out of time. Overall, nine data points were missing because one subject who did not complete Phase 3 also did not complete Phase 4.

In Phases 3, 4, and overall, the ordering effect was significant in the analysis of accuracy. The incomplete trial data in Phase 4 and overall impacted the ordering effect. When accuracy was re-analyzed in Phase 4 and overall excluding incomplete data, the ordering effect was not significant. However, in Phase 3, the ordering effect was still significant. The number of missing data points in Phase 3 was low and therefore did not have as great of an impact on the analysis. The sets of trials for each problem were not conducted at regular intervals. Therefore, some subjects had two class days between the exposure to the concept in class and the tutoring session while others had three class days. Other environmental influences included the students' lack of sleep, anxiety caused by being away from home, and workload, for example, tests and homework. The trials for the last task coincided with the final tests in each of the subjects' classes. The eighth problem covered a concept that was briefly covered in the math class prior to the subjects applying the concept. In addition, while subjects were able to practice basic skills repeatedly in the math problems (for example, simplifying equations), the concepts presented did not build on the concepts presented in previous math problems. The exception was math problems 3, 4, and 5, which covered geometry skills using different shapes. The mean accuracy of these three tasks was not significantly different.

In the analysis of process time, the ordering effect was significant in Phases 1, 2, and 3. For each of these cases, the ordering analysis was conducted on the absolute difference between the observed and expected process times. Phases 1 and 2 resulted in a significant effect. However, Phase 3 order was no longer significant. Because order remained significant, the original analysis of process was reviewed. In reviewing Phase 1, the results were interesting. In math problems with expected times of 10 minutes, the difference in the mean times was not significant. Similarly, problems with expected times of 5 minutes, differences between the mean process times were not significant. And the problem with an expected time of 15 minutes was not significantly different from any of the other math problems. In Phase 2, the comparisons of the expected and actual times did not explain all of the differences. Two of the five problems with expected times of 15 minutes had significantly different process times from the other three problems. However, one problem had an expected time of 5. This process time for this problem was significantly different from two of the problems expected to take 15 minutes and the one problem expected to take 20 minutes. The process times of problems 5 and 6 might be explained through the type of

problem. Problem 5 involved a cylinder embedded into the cone. For subjects to see how to solve this problem, they had to recognize this was a problem of similar triangles. This was very difficult for several subjects to understand. The figure given was 3-dimensional. However, to solve the problem, the subject had to translate the problem into 2-dimenions. Many subjects planned to solve it as a 3-dimensional problem and would get to a point in their work where they couldn't figure out the next step. They asked the tutor for help. In many cases, the tutor had a difficult time trying to get the subject to see the problem in 2 dimensions. In the sixth problem, the concept was based on trigonometry. This problem was a symbolic representation as opposed to a numerical problem. Subjects often solved this problem without realizing it in the planning phase.

5.8 Conclusions

There were several distinct conclusions that were drawn from this study. First, analyzing the tutoring process based on the four-phased problem solving process generally was not important for determining the optimal tutoring system. Second, accuracy of the math problem was similar regardless of the communication media and feedback cue. This implied that students using the computer-mediated communication conditions for tutoring should have similar performance compared to collocated tutoring. Third, generally, subjects took longer to solve the math problems when they used text-based communication compared to media with audio and video channels.

Subjects were more satisfied was higher using collocated communication compared to either email or video teleconferencing. In addition, subjects were generally more satisfied when they used the chatroom than email. While the feedback cue negatively impacted subject satisfaction, the tutor appeared more satisfied with the feedback cue than without the feedback cue.

5.8.1 Design Implications

The computer-mediated communication technology in this study did not improve tutoring based on dependent variables. However, many of the communication media had comparable results to collocated communication. This indicated several practical implications. The first was that computer-mediated communication was a viable option for tutoring. This result is important when financial resources are limited. Through the use of a chatroom, many students could be tutored simultaneously with a single tutor.

Currently, state-of-the-art video conferencing systems are out of the realistic realm of affordability for most students. High-speed fiber optic cables are also supposed to help eliminate some of the communication problems with video teleconferencing. Improvements in the frame rates and sound have been shown positively impact performance and subjective perceptions (Kies et al., 1997).

For a successful tutoring session, the tutor must be able explain to the student how to solve the problem and the student must understand the steps involved. If the student ended the tutoring session with a correctly solved problem but he or she did not understand the work, the tutoring session failed to accomplish the goal. Students who did not understand their answers after receiving tutoring assistance might doubt their ability to work similar problems. This could negatively affect the motivation a student has to seek assistance. The perceived understanding in the chatroom, video teleconferencing, and collocated communication was similar.

Generally, the audio-visual linked communication modes were faster than the text-based modes. However, the multiple users that were provided to simulate an actual chatroom environment probably

influenced the process time in the chatroom. Subjects did not appear to notice the time difference in the chatroom. Many subjects commented that the chatroom was fast. This perception was probably a result of the immediacy of feedback that the chatroom enabled. In addition, the subjects' satisfaction in the chatroom was similar to the satisfaction in collocated communication. This implied that students who used the chatroom were not negatively influenced by the time. In fact, most subjects perceived video teleconferencing took longer for tutoring than the chatroom. The perceived ease of use of the technology supported the satisfaction perceptions.

One important issue was omitted from this discussion. In this research, there was the potential for subjects to misuse tutoring. The chatroom was one medium that facilitated the potential misuse. In the chatroom there were multiple users working on the same problem. An individual user could have relied on the other participants for answers. This tutor commented only once this appeared to occur. Therefore, if a chatroom was implemented in a tutoring system, the tutors must work to involve the participants equally. In addition, the tutors must be wary of abusers. While these were all issues for concern, using the chatroom for tutoring was still a viable method for serving a large number of students.

5.8.2 Future Research

Due to the subjects' daily schedule and scheduling the subjects' time in the laboratory, subjects were only able to participate in this study for two hours each week. The results might have been affected by the imposed time limit. In Phase 4, 12.5% of the trials resulted in incomplete data because subjects ran out of time. Overall 14% of the data was incomplete. Some research has shown that in organizations, the same communication took place using CMC compared to collocated, however, the communication took longer (Fowler et al, 1980). This result was found for communication that occurred without time limits. Therefore, one area for future research would be to study tutoring in terms of the amount of communication without time limits.

Group tutoring was the original method to be used in this study. Several of the variables might have been affected if groups were used. In addition, the feedback cue might not have caused such strong negative reactions in group tutoring. Several of the subjects pointed out they saw the usefulness of the feedback cue in the chatroom so the tutor would have an easier time trying to figure out who needed help. The feedback cue might have helped a confused subject gain the tutor's attention more easily if there were a large number of students being tutored.

Again, in one-on-one tutoring, the feedback cue did not enhance the tutoring process from the subjects' perspective. However, in a large classroom situation a feedback cue from the students to the instructor could be very helpful. From Hendrick (1984), college age students tend to be system II, general negativism, in their cognitive complexity. In addition, most students have not been exposed to a variety of cultures. Their degree of professionalism is fairly low; they are in the process of learning to increase their professionalism. Many students fear the reaction of not only their peers but also of their instructor if they admit they do not understand what the instructor is teaching. A feedback cue, might be one method to reduce the fear.

Redesigning the feedback cue to be on-line is potential area for future research. The subjects commented that the feedback cue was intrusive. Changing the task focus required time (Glass et al., 1979). Therefore, changing attention from the problem – to the computer – to the feedback cue took time. If the feedback cue was within the computer interface, the change in the mental focus would still have to occur. However, two tasks take place in the same environment. In computer-mediated communication, attention was already divided between the monition/keyboard and the worksheet on which they solved their problem.

Adding the feedback cue, as a separate piece of hardware added to the number of jobs they had to keep track of; and as many subjects put it, they simply forgot about it. In addition, changing the levels of understanding to two extremes might help increase the feedback cue's use. The extremes are much easier to judge than an incremental change (Glass et al., 1979).

The problem solving process used in this research imposed a structure to the tutoring process. Students reacted very differently to it. One subject commented at the end of each trial that he did not like the problem solving the method. Most freshman college students are in their teens. Many teens rebel against imposed structure. In terms of their cognitive complexity, many students are in system II. In addition, the problem solving process might have provided too much structure for the math problems being tutored. Therefore, another interesting study would be to remove the structure from the tutoring process and determine how the accuracy, time, and satisfaction are affected.

Finally, the use of whiteboards to facilitate the communication process would be an important area to explore for tutoring. Would the use of whiteboards create more of a sense of presence and therefore positively affect the computer-mediated process. The whiteboard is basically an electronic version of pencil and paper. Through the whiteboard the tutor and student could easily show figures and equations which might be hard to portray using keyboard characters.

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Appendices

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Appendix A.1 Subjects' Directions and Exercises

Appendix A.1 contains the directions and exercises the subjects received. The subjects were allowed to keep the directions & exercises for the duration of the trial. These materials were laminated to ensure each subject had the same information in each experimental condition.

Appendices A.1.1 - A.1.2 contain the general instructions for the tutoring process. Appendix A.1.3 contains directions for the feedback cue. Appendix A.1.4 contains directions for email communication. Appendix A.1.5 contains directions for chatroom communication and Appendix A.1.6 contains directions for video teleconferencing communication. Instructions that were more than 1 page were printed out front and back to reduce paper clutter at the workstation.

For chatroom communication, two additional persons were used as controls. Each of these people received the same directions the subject received for the general tutoring process and for the feedback cue. In addition, each person received a personalized set of chatroom instructions and exercises. For example, one person received a set of instructions for the call name "Hokie" and the other for the call name "VT."

Appendix A.1.1 General Instructions – No Feedback Cue

Directions:

Please read through the following instructions and if you have any questions please ask.

In today's tutoring session you will be communicating with your tutor using _____. Your task is to solve a math problem. Show all work on the worksheets provided. Your tutor will guide you through a problem solving process to solve this problem. Please do not work ahead of the directions your tutor gives to you. The four phases of the problem solving approach are 1. determine what the problem is asking for, 2. plan how you will solve the problem, 3. actually solve the problem, and 4. review the solution with the tutor.

Just to re-emphasize some points:

1. **Show all work on your worksheet**
2. **Do not work ahead of the tutor's instructions**

You will have 1 hour to complete the problem. The tutor will be keeping track of time. Don't rush, but work as accurately and quickly as you can.

A math book, calculator, worksheets, and pencil have been provided for your use.

Appendix A.1.2 General Instructions – Feedback Cue

Directions:

Please read through the following instructions and if you have any questions please ask.

In today's tutoring session you will be communicating with your tutor using _____. In addition, you will be using a feedback cue to help you communicate with the tutor. Your task is to solve a math problem. Show all of your work on the worksheets provided. Your tutor will guide you through a problem solving process to solve this problem. Please do not work ahead of the directions your tutor gives to you. The four phases of the problem solving approach are 1. determine what the problem is asking for, 2. plan out how you will solve the problem, 3. actually solve the problem, and 4. review the solution with the tutor.

Just to re-emphasize some points:

1. **Show all work on your worksheet**
2. **Do not work ahead of the tutor's instructions**
3. **You should have a feedback cue on at all times to show your level of understanding to the tutor**

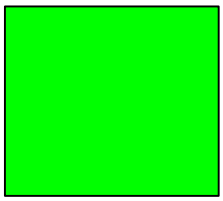
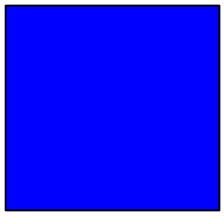
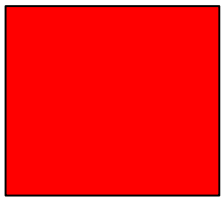
You will have 1 hour to complete the problem. The tutor will be keeping track of time. Don't rush, but work as accurately and quickly as you can.

A math book, calculator, worksheets, and pencils have been provided for your use.

Appendix A.1.3 Instructions – Feedback Cue

A feedback cue is a way of non-verbally telling the tutor how well you understand what is going on in the tutoring session. In this experiment we are going to represent your level of understanding with three colors of lights. You have three power strips by your workstation. You can communicate your level of understanding of the material you are working on to the tutor by turning on the appropriate power strip. When your level of understanding changes, turn off the switch representing your previous level of understanding and turn on the switch representing your current level of understanding.

When you understand everything, you have a high level of understanding which is represented by a green light. When you aren't sure you understand everything but you think you are close to understanding it, you have a medium level of understanding which is represented by a blue light. And when you are completely confused, you have a low level of understanding which is represented by a red light. Each power strip has a label. The following is a summary of the power switch labels and the corresponding meanings.

Feedback Cue Label (Power Switch Label)	**Description**
	You completely understand all concepts and have no questions
	You are slightly confused. You think you understand some of the concepts, but not all of the concepts.
	You are really confused. You don't really understand the concepts.

Use this cue continuously through out this session to let the tutor know your level of understanding. For example, while you understand everything, the power strip with the high level of understanding label, green, should be turned on. Then if you suddenly become a little confused, turn off the high level power strip and turn on the power strip with the medium level of understanding, blue. Don't forget to turn off one power strip before turning on a new one.

Cue Test:

The tutor is at his workstation. Practice using your cue. Turn on the switch representing a low level of understanding. Wait for the tutor to confirm that you picked the correct level. Then change your level of understanding to high. Again wait for the tutor's confirmation. If you are still unsure about this system please ask the researcher for help.

Directions for using Eudora Light (Email)

Closing and Opening Mailboxes:

You should be able to see both your "In" and "Out" mailboxes at the same time on your monitor. You receive messages in the "In" mailbox. When you send a message, it is stored in the "Out" mailbox. The top line of each window tells you the name of the mailbox. The first column of the mailbox tells you the status of the message; the second column tells you the name of the sender; the third column has the date and time the message was received (or sent); and the fourth column has the subject of the message. In the first column of the "In" mailbox, when you get a new message that hasn't been read, the first column will have a dot (●) in it. Once you have read the message, the first column will become empty. And if you reply to the message, the first column will have a "R" in it. The first column of the "Out" mailbox tells you the status of your outgoing mail. If you have sent a message, the first column will have an "S" in it. If you have saved a message, but haven't send it, the first column will have a dot (●) in it.

To close a mailbox, left click on the "✖" in the upper right hand corner of the *mailbox* window (make sure it isn't Eudora's main window). If you accidentally close Eudora, please let the researcher know immediately. To open a mailbox, left click on "Mailbox" in the menu bar. Then left click on the mailbox you want to open, "In" or "Out". Please do not use the "Trash" mailbox. ***Do Not delete any messages!***

Receiving your messages (also called Checking Email):

Left click on "File" in the menu bar, then left click on "Check Mail". If you are asked for a password enter: PaigeSmith (type this exactly as you see it). You should check for mail very often during your tutoring session. Do not wait for the computer to check your mail or you will not finish your math problem.

Reading your messages:

From the "In" mailbox, left double click on the message you want to read. Note, you can open messages from either the In or Out mailbox. Unread messages have a dot (●) next to them. You can open and close an email message as many times as you want.

Description of the Email Window for Messages You Have Received:

The italicized text explains what each area of the email window is.

To: Student1@hci.ise.vt.edu (or student) This is your *PID or nickname*
From: Tutor@ hci.ise.vt.edu *This is the PID of the sender*
Subject: *This is the subject of the message. Not all emails will have this filled out – it is optional.*
Cc: *Blank.*
Bcc: *Blank*
Attachments: *Blank.*

This is where your message appears

In order to send and receive email, you must have an email address which is called a PID. Your PID is Student1@hci.ise.vt.edu To send email to the tutor and your other group member use the following information:

Person	Nickname	PID
Tutor	tutor	Tutor@hci.ise.vt.edu

You may use either the nickname or the PID to send email.

Note, you cannot make changes in this email window. You must either create a new message or reply to the sender in order to type in your own message. These functions are explained under the Message option.

Options to Send Email:

There are several ways for you to send email. And these are described in the Message options below. To select one of the options, left click on Message and then left click on the option you want to select. This will open the email window for you. Note, when responding to an email, the easiest option to use is "Reply".

Description of options you might need to use under "Message" in the menu bar:

New Message: Opens a blank email window. Only your return address is supplied. You must enter the PID or nickname of the person you want to send the message to in the "To:" line. The "From:" line is automatically filled in with your address.

Reply: Lets you reply to a message that you have received. When choosing this option, you must have the email you are replying to open. It will open an email window with a copy of the email. Each line of the message you are replying to will be preceded by an arrow (>). The address of the person who you are replying to will appear in the "To:" line and your address will appear in the "From:" line. In addition, you should see "Re:" in the subject line followed by the subject of the email (if there was a subject typed in). Then you can type your message either above or below the old message. You can also edit the old message if you want to make changes.

New Message To: This lets you send a new message to a person who has a nickname. (A nickname has been created for the tutor. The tutor's nickname is "tutor".) By choosing a nickname you will open a blank email window. The nickname you chose will appear in the "To:" line and your return address will appear in the "From:". You must fill out everything else.

Note, there are more options under the Message option. However, the ones listed above are the most frequently used options.

Hints to keeping your Email organized. Once you are done with an email message (and have responded to it if you want to) close the message window. To do this, left click on the "✖" in the upper right hand corner of the *message* window (make sure it isn't Eudora's main window). If you accidentally close Eudora, please let the researcher know immediately.

Description of the Email Window for Messages You Are Sending:

To: ***This is where you enter the PID or Nickname of the person you want to send a message to***
From: Student1@hci.ise.vt.edu ***This is your PID and it will be automatically put here by Eudora***
Subject: ***This is where you enter the subject of your message – you can leave this blank***
Cc: ***Leave Blank.***
Bcc: ***Leave blank***
Attachments: ***Leave blank.***

This is where you type your message

Moving from one area of the email window to another:

To move from one area of the message window to another area, place the mouse arrow on top of the area you want to be in and left click. The cursor will appear on the line and you can begin typing. The enter key on your keyboard will create a new line – it will not send the message and it will not move your cursor from one area of the email window to another.

To send a message:

Once you have finished typing in your message, place the mouse arrow over the "Send" button and left click. You will see a small window which will tell you Eudora is in the process of sending your message. When the box goes away your message has been sent. It will now be logged into your "Out" mailbox.

Practice Using Email:

1. See if you have any messages by checking your email.
2. Read any new email messages and respond to them

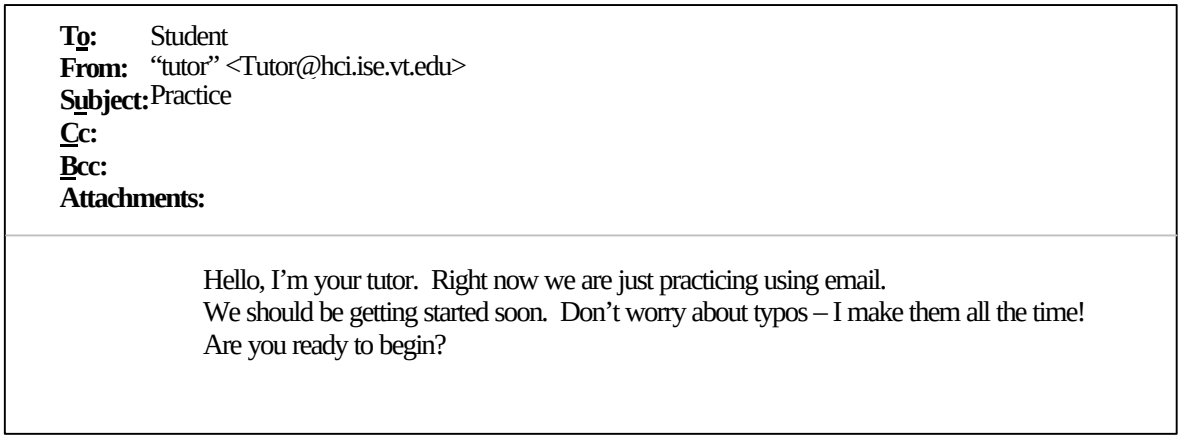
If you are stuck completing any of these tasks, here are the steps you should take to carry them out.

1. See if you have any messages:

Step 1: Left click on "File" in the menu line.
Step 2: Left click on "Check Mail".
Step 3 (may be optional): If you are asked for a password, enter PaigeSmith

2. Read any new messages and respond to the one sent by the tutor.

Step 1: Open the In mailbox (if it is not already open) by 1) left clicking on "Mailbox" in the menu bar and 2) left clicking on "In".
Step 2: Open the new message by left double clicking on the unread message sent by the tutor. (It should have a dot in the first column, and "tutor" should appear in the second column.) When the message opens, it should appear similar to this:



Step 3: While in the tutor's message, left click on "Message" then click on "Reply" (don't confuse this with "Reply To". The "To:", and "From:" and "subject lines should already be filled out. The message window should look similar to this:

To: tutor
From: "student1" <Student1@hci.ise.vt.edu>
Subject: Re: Practice
Cc:
Bcc:
Attachments:

At 10:46 AM 6/21/97 –0400, you wrote:
>Hello, I'm your tutor. Right now we are just practicing using email.
>We should be getting started soon. Don't worry about typos – I make them all the time!
>Are you ready to begin?

Note that the tutor's message is included in your reply. You can tell this is part of the old message because each line is preceded by an arrow (>). Every time this message is replied to another arrow will appear.

Step 4: Left click in the message area and type your message. For example, "I'm ready to begin."

You can either delete the old message, type above or below the old message, or you can add to the old message. Note, if you chose to add to the old message, it might be hard for the next reader to see what you've changed. Some suggestions to make it easier for your reader to follow your changes/additions are 1) to use all capital letters, or 2) to add lines around the area you are typing.

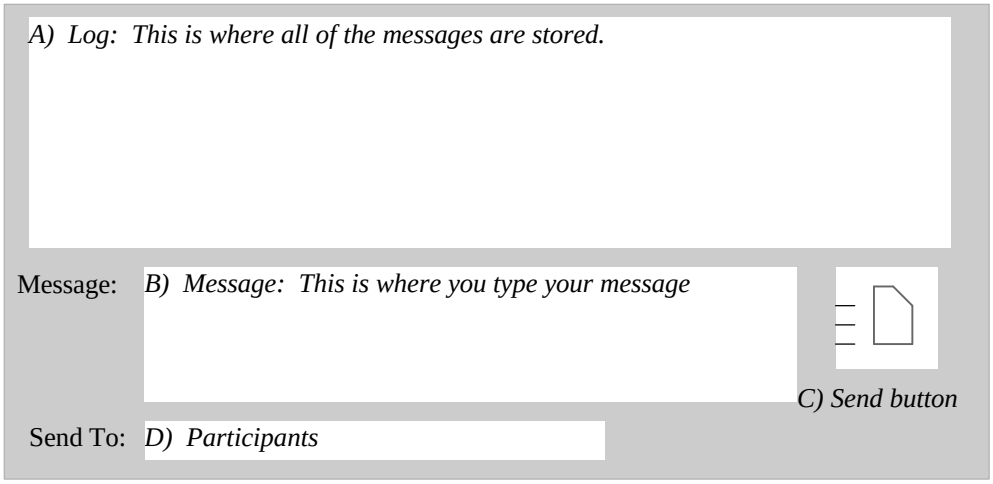
Step 5: Send the message by left clicking on the Send button.

Step 6: Close the tutor's email message by clicking on the "✖" in the upper right hand corner of the message window (be careful not to close Eudora's main window.) If you are unsure which "✖" to click on, please ask.

Directions for Using Microsoft NetMeeting (Chatroom)

If you accidentally close the chatroom at any time, tell the researcher immediately.

The screen in front of you is already open to the chatroom. Your screen looks similar to this: (The italicized text are labels and descriptions of each screen area.)



Description of Screen Areas:

A) Log: This is where all of the messages are stored. Each message has a name and time attached to it. The name is that of the person who wrote the comment and the time is the time that you received the message. Once this screen is full, the window will allow you to scroll up and down using either the arrow up and down keys or by using your mouse to click on the scroll bar. You cannot type in this window. The following is a list of names that you might see during your chat session

Name	**Person the Name Belongs To**
student1	This is your name
tutor	This is the tutor's name
Hokie	This is the name of another student you might work with
VT	This is the name of another student you might work with

B) Message: This is where you type your message. Your message can be longer than the window size. To read over messages that you have typed that are larger than the window, use the up/down arrows on your key board (there is no scroll bar). You can move around in this window by either using your mouse or the arrow keys on your keyboard.

Note, due to the large screen setting, it is easy for information to be cut off. If your message has no spaces and is more than3/4 of the Message Window long, it will not be completely visible in the message log. This situation might occur when you type in equations. To avoid this problem, use spaces in your equations.

C) Send Button: Left click on this button when you are ready to send your message. Pressing enter on the keyboard will also send your message.

D) Send To: This shows you who is included in your chatroom conversation. It is currently set for all (which includes all the students and the tutor). **Do not change this setting**.

Editing Functions (under "Edit" in the Menu Bar):

Copy: Copy lets you put the same text in more than one place. The text you want to copy must be highlighted. To highlight text in the Message Window, left click on the beginning of the text you want copied and hold the left button down as you drag the mouse to the end of the text you want copied. When you release the left mouse button, the text should be highlighted. To highlight text in the Log Window just left click on any part of the message you want to copy and the entire message will be highlighted. Left click on "Edit" in the menu bar and left click on "Copy".

Note, when you copy messages in the Log Window, you must copy entire messages including the sender and time of each message. Any unwanted text that is included can be deleted from the Message Window once it is pasted in place.

Cut: Cut lets you move text from one place to another. The text you want to cut must be highlighted. To highlight text in the message window, left click on the beginning of the text you want cut and hold the left button down as you drag the mouse to the end of the text you want cut. When you release the left mouse button, the text should be highlighted. Left click on "Edit" in the menu bar and left click on "Cut". The text will disappear until you paste it into place.

Note, you cannot cut messages from the Log Window (you can only copy them).

Paste: Once you have copied or cut a section of text, Paste puts the text in at the location of the cursor. After you have cut/copied a section text, put the cursor at the location where you want the text pasted. Then left click on "Edit" in the menu bar and left click on "Paste". The text should appear in the location of your cursor.

Practice Using Chat:

The tutor has asked you a question. Read the log to find out the answer and send him a reply.

If you are stuck completing this task, here are the steps you should take to carry them out.

Step 1: To read the message, look in the message log. The tutor has send you a message that should say, "Hi. This is just a practice message. So I know you know how to use the chatroom, send a copy of this message back to me, but omit everything but the last sentence. Use your cut and paste functions to do this instead of retyping everything. Then tell me if you are ready to get started."

Step 2: To copy the logged message into your message window so you can re-send it, left click on the message in the log window. Then left click on "Edit" in the menu bar and then left click on "Copy".

Step 3: To paste the copied message into the message window, move the mouse arrow to the message bar and left click. Then left click on "Edit" in the menu bar and then left click on "Paste". The message will now appear in your message window. You will see the sender's name, time, and the complete message in your window.

Step 4: To edit the message so that just the last line is showing in your window, left click on the beginning of the text and holding down the left mouse button, drag the mouse to highlight all of the text you want to delete. Once the text is highlighted, release the left mouse button. Then press the delete key on your keyboard.

Step 5: To tell the tutor you are ready to begin, left click after the text in the Message window. Then type in your message, for example, I'm ready to begin.

Step 6: To send the message press the Enter key on your keyboard.

Step 7: Look at the Log to see you message. It will appear once you press enter.

Please ask if you have any questions.

Appendix A.1.6 Instructions – Video Teleconferencing

Directions for CU-SeeMe (video teleconferencing)

You have two video windows open. The one labeled student1 is you. The one labeled tutor is your tutor.

To Speak to the Tutor:

In the window with the "Audio" label, you will see a button labeled "Push to Talk". Left click on your mouse and hold while you are speaking. If you let go, your message will be cut off. Please speak very clearly and a little slower than your normal speaking pace. Otherwise, it might be hard to understand the audio.

To Send a Message to the Tutor:

In the window with the "Chat" label, you will see two white boxes. The lower box is where you type your message. To send the message press "enter" on your key board. The top box is the message log. This is where you will see your message once it has been entered.

Practice Using Video Teleconferencing:

Tell the tutor you are here verbally. Then tell him what color shirt he is wearing. Then send him a message asking him if he is ready and if he heard you. Then you can practice talking to one another.

If you have problems, these are the steps:

Step 1: Press down the "Push to Talk" button in the Audio window.
While this button is pressed say "Hi tutor, I'm here. You are wearing a _____ colored shirt today"

Step 2: Click on the Chat Window. In the bottom white box type "Are you ready? Did you hear me?"
The tutor will either send you or tell you a response.

Please ask any questions you might have about using video teleconferencing.

Appendix A.2 Tasks, Solutions, and Accuracy Criteria

Appendix A.2 contains the math problems, solutions, and criteria the expert used to determine the accuracy of each problem. The problems are shown in the order the subjects received them. The criteria and the associated point assignments used to determine the accuracy are shown in red. Table A.2 contains a list of problems and the mathematical concept covered by each problem. Math problems 1, 3, 4 and 5 came from Swokowski's (1991) calculus textbook and math problems 2, 6, and 8 came from Thomas and Finney's (1996) calculus textbook. The ASPIRE '97 mathematics instructor developed problem 8.

Table A.2 Concepts covered in mathematics problems and expected completion times

		Expected Time To Complete (minutes)			
Problem No.	Concept	Phase 1	Phase 2	Phase 3	Phase 4
1	review	5	15	15	10
2	straight lines	10	15	5	15
3	geometry	10	15	10	10
4	geometry	5	10	15	15
5	geometry	5	15	10	15
6	trigonometry	15	15	10	5
7	functions and inverse functions	5	5	20	15
8	natural logarithms & exponents	5	20	10	10

Math Problem #1 (Swokowski, 1991; p. 13)

For a drug to have a beneficial effect, its concentration in the bloodstream must exceed a certain value, *the minimum therapeutic level.* Suppose that the concentration c of a drug t hours after it is taken orally is given by $c = \frac{20t}{(t^2+4)}\frac{mg}{L}$. If the minimum therapeutic level is 4 mg/L, determine when this level is exceeded.

Solution:

Phase 1:

Determine the time interval, t, when the minimum therapeutic level is exceeded. (t when c > 40 mg/L)

{Find when (time, t, interval)} (3 points)
{The concentration c is > 4, i.e., t when c > 4)} (7 points)

Phase 2:

known: $c = \frac{20t}{t^2+4} mg/L$ = concentration of a drug (1 point)
minimum therapeutic level, c = 4 mg/L (1 point)

unknown: t (1 point)

$$c = \frac{20t}{t^2+4} mg/L$$

$$4 < \frac{20t}{t^2+4}$$ (5 points)

Plug c > 4 into equation and solve inequality for t. (1 point)

Solve by multiplying both sides by (t^2 +4). Then get all terms on one side of the equation. Solve for t. (1 point)

Phase 3:

$$4 < \frac{20t}{t^2+4}$$

$$4 - \frac{20t}{t^2+4} < 0$$

$$\frac{4(t\ +4)}{t^2+4} - \frac{20t}{t^2+4} < 0$$

$$\frac{4t^2+20t+16}{t^2+4} < 0$$

always positive

$$\frac{t^2 - 5t + 4}{t^2 + 4} < 0$$ (1 point)

$$\frac{(t-4)(t-1)}{t^2+4} < 0$$ (2 points)

t = 4 t = 1 (2 points)

	t - 4	t - 1	t2 + 4	<0
(0,1)	-	-	+	+
(1,4)	-	+	+	-
(4,∞)	+	+	+	+

(4 points for table)

This one

Exceed 4 for 1<t<4 hours (1 point)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

{break down of phase 3:

- if 1/2 right -2 points
- (1,4) = 2 points
- correctly solved = 3 points}

Math Problem #2 (Thomas & Finney, 1996; p. 16)

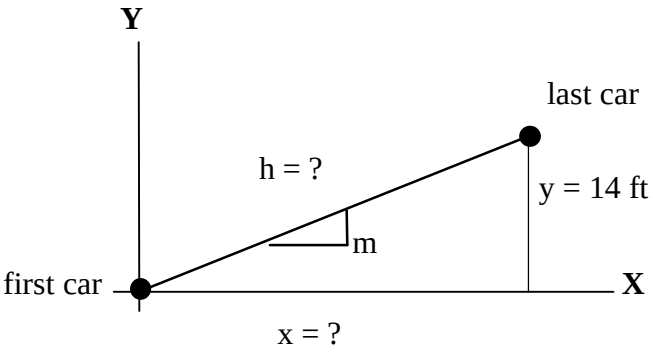
The Mt. Washington Cog Railway. Civil engineers calculate the slope of roadbed as the ratio of the distance it rises or falls to the distance it runs horizontally. They call this ratio the grade of the road bed, usually written as a percentage. Along the coast, commercial railroad grades are usually less than 2%. In the mountains, they may go as high as 4%. Highway grades are usually less than 5%.

The steepest part of the Mt. Washington Cog Railway in New Hampshire has an exceptional 37.1% grade. Along this part of the track, the seats in the front of the car are 14 ft above those in the rear. About how far apart are the front and rear rows of the seats?

Solution:

Phase 1:

Find the distance, h, between the first and last seats.



(-7 points for using 14 ft as height but looking for the wrong distance)
(-1 point for an unclear statement)

Phase 2:

known: grade = 37.1% = slope (m) (1 point)
therefore, m = 0.371 (2 points)
height, y distance = 14 ft (1 point)

unknown: x distance
length of the hypotenuse = distance between 1st and last car (1 point)

equations: line: $y = mx + b$
m = rise/run
Pythagorean theorem: $c^2 = a^2 + b^2$

find x: $y = mx + b$
find x from m = rise over run. then use the Pythagorean theorem to find the length of the hypotenuse. (5 points)

Phase 3:

14 ft = 0.371x + 0
x = 37.74 ft (5 points)

find h: $h = (x^2 + y^2)^{1/2}$
$h = (37.74^2 + 14^2)^{1/2}$
$h = (1620.31)^{1/2}$
h = 40.25 ft (5 points)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Math Problem #3 (Swokowski, 1991; p. 25)

An open-top aquarium of height 1.5 feet is to have a volume of 6 ft^3. Let x denote the length of the base, and let y denote the width (see figure). Simply your answers completely.

(a) Express y as a function of x.
(b) Express the total number of square feet S of glass needed as a function of x.

Solution:

Phase 1:

Express y (width) as a function of x (length) (5 points)
Express the total number of square feet, S, of glass needed as a function for x (5 points)

Phase 2:

known: height = 1.5 ft = 3/2 ft (1 point)
volume = 6 ft^3 (1 point)

unknown: x , length (1 point)
y(x) (1 point)
Total number of square feet S of glass(x) = Surface Area (1 point)

equations: v = Lwh (x = length = L, y = width = w) (2 points)
S = 2(wh) + 2(Lh) + Lw (3 points)

Open at the top therefore don't multiply by 2

Phase 3:

a) v = L w h
6 = x(y)(3/2)
6 = 3/2 xy
y = 12/(3x)
y = 4/x (3 points)

b) S = 2[(3/2)y] + 2[(3/2)x] + xy
S = 3y - 3x + xy
S = 3(4/x) + 3x +x(4/x)
S = 12/x + 3x + 4 (7 points)

(Note: careless error - 1 point; 1 of 3 S terms wrong - 2 points)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)
(note: part a. 1 point, part b. 4 points)

Math Problem #4 (Swokowski, 1991; p. 13)

The rate at which a tablet of vitamin C begins to dissolve depends on the surface area of the tablet. One brand of tablet is 2 cm long and is in the shape of a cylinder with hemispheres of diameter 0.5 cm attached to both ends (see diagram). A second brand of tablet is to be manufactured in the shape of a right circular cylinder of altitude 0.5 cm.

Find the diameter of the second tablet so that its surface area is equal to that of the first tablet.

Solution:

Phase 1:

Find the diameter of the second tablet so its surface area is equal to the diameter of the first tablet. (10 points)

Phase 2:

known: Tablet 1 (cylinder tablet):
L1 = 2 cm (1 point)
D1 = 0.5 cm (diameter) (1 point)

Tablet 2 (right cylinder tablet):
altitude = 0.5 cm (1 point)

unknown: D2 (diameter of tablet 2) (1 point)
SA1 (surface area of tablet 1),
SA2 (surface area of tablet 2)

equations: $SA_{\text{rt. cir. cyl.}} = 2\pi rh$
$SA_{\text{sphere}} = 4\pi r^2$
$2A_{\text{circle}} = 2\pi r^2$

SA1 = surface area of tablet 1
$= SA_{\text{rt. cir. cyl.}} + SA_{\text{sphere}}$
$= 2\pi rh + 4\pi r^2$
(2 points)

SA2 = surface area of tablet 2
$= SA_{\text{rt. cir. cyl.}} + 2A_{\text{circle}}$
$= 2\pi rh + 2\pi r^2$
(2 points)

Simplify and set SA1 = SA2 and solve (2 points)

Phase 3:

SA1 $= 2\pi(1/4)(2 - ½) + 4\pi(1/4)^2$
$= 2\pi(1/4)(3/2) + (4\pi)/16$
$= (¾)\pi + \pi/4$
$= \pi$
(3 points)

SA2 $= 2\pi r(1/2) + 2\pi r^2$
$= \pi r + 2\pi r^2$
(3 points)

So

$SA1 = SA2$
$\pi = \pi r + 2\pi r^2$
$1 = r + 2r^2$
$0 = 2r^2 + r - 1$
$0 = (2r - 1)(r+1)$

$2r - 1 = 0$ $\quad$ $r + 1 = 0$
$r = ½$ $\quad$ $r = -1$ (impossible) $\quad$ (3 points)

so $r = ½$ cm $\quad$ **diameter = 2r = 1 cm** $\quad$ (1 point)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Math Problem #5 (Swokowski, 1991; p. 26)

A right circular cylinder of radius *r* and height *h* is inscribed in a cone of altitude 12 and base radius 4, as illustrated in the diagram. Simply your solution completely.

1) Express *h* as a function of *r*.
2) Express the volume *V* of the cylinder as a function of *r*.

Solution:

Phase 1:

a) Write height of cylinder, h, as a function of the radius of the cylinder, r. (5 points)
b) Write volume, V, of cylinder as a function of r, radius of the cylinder. (5 points)

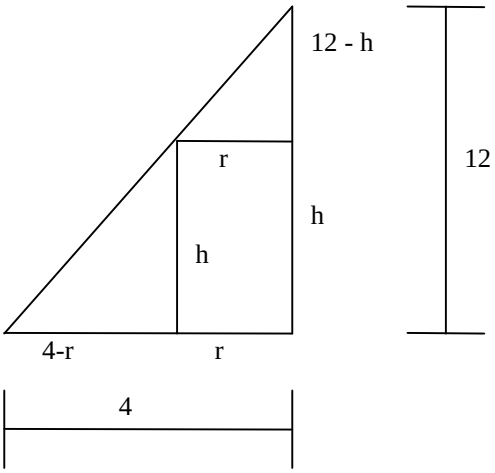
Phase 2:

known: $r_{\text{cone base}} = 4$ (1 point)
$h_{\text{cone}} = 12$ (1 point)

unknown: r, radius of cylinder (1 point)
h, height of cylinder (1 point)
v, volume of cylinder (1 point)

equations: radius/height ratio
$V_{\text{cylinder}} = \pi r^2 h$

need to use similar triangles



(1 point for figure)

$$\frac{\text{radius}}{\text{height}} = \frac{\text{radius cone}}{\text{height cone}} = \frac{\text{radius cylinder}}{\text{height cylinder}}$$

$$\frac{4}{12} = \frac{4-r}{h}$$

or

$\frac{4}{12} = \frac{r}{12-h}$ (2 points)

Phase 3:

a) $4h = 12(4 - r)$
$h = 3(4 - r) = 12 - 3r$ (7 points)

b) $V_{cylinder} = \pi r^2 h$
$= \pi r^2(12 - 3r)$
$= 3\pi r^2(4 - r)$ (3 points)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Math Problem #6 (Thomas et al., 1996; p. 743)

The trammel of Archimedes. The mechanical system pictured here is called the trammel of Archimedes. It consists of a rigid bar of length L, one end attached to a roller that rolls along the *y*-axis. At fixed distance R from this end, the bar is attached to a second roller on the *x*-axis. Let P be the point at the free end of the bar and let θ be the angle the bar makes with the positive *x*-axis.

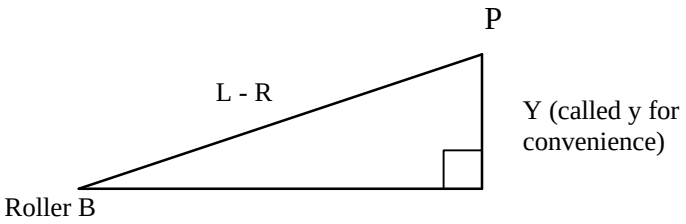
Functions x = f(θ) and y = g(θ) together describe the path of P.

a) Find an equation for x in terms of θ.
b) Find an equation for y in terms of θ.

Solution:

Phase 1:

Write an equation for x in terms of theta (5 points)
Write an equation for y in terms of theta (5 points)



Phase 2:

known: length of bar = L
distance from roller A to roller B is R
The angle between the bar and the x-axis is theta
(1 point)

unknown: x -- 1 coordinate of P
y -- 1 coordinate of P
(1 point)

equations: $\sin\theta = \text{opp/hyp} = y/(L-R)$ (2 points)
$\cos\theta = \text{adj/hyp} = x1/R$ (2 points)
$\cos\theta = \text{adj/hyp} = x2/R$ (2 points)

Solve for x1, x2, and y (1 point)
Add x1+x2 to find x (1 point)

Phase 3:

$\sin\theta = y/(L-R)$
Therefore, $y = (L-R)\sin\theta$ (3 points)
$x = x1 + x2$

$\cos\theta = x1/R$ and $\cos\theta = x2/(L-R)$
Therefore $x1 = R\cos\theta$ and $x2 = (L-R)\cos\theta$
(3 points) (3 points)

so

$x = x1 + x2 = R\cos\theta + (L-R)\cos\text{theta} = l\cos\theta$ (1 point)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Math Problem #7 (Anderson, 1997)

A scientist realizes that she has calculated results using function $f(x) = \frac{3x+2}{2x-11}$ when she should have been using its inverse. As her lab assistant, you must find the inverse of f. To partially verify your answer, compose $f\left(f^{-1}(x)\right)$.

Solution:

Phase 1:

Find $f^{-1}(x)$ (5 points)
Calculate $f(f^{-1}(x))$ or partially verify (5 points)
(Note, if just say verify, - 2 points; say to do both $f(f^{-1}(x)$ and $f^{-1}(f(x))$, - 2 points)

Phase 2:

known: f(x) (1 point)
unknown: inverse of x (1 point)
equation: f(x)= (3x +2)/(2x-11) (2 points)

switch x and y in f(x) (2 points)
solve for y (2 points)
and compose $(f(f^{-1}(x))$ (note, can also be written as $(f \bullet f^{-1})(x)$ (2 points)

Phase 3:

$$y = \frac{3x+2}{2x-11}$$

$$x = \frac{3y+2}{2y-11}$$ (1 point)

x(2y - 11) = 3y + 2 (1 point)

2xy - 11x = 3y + 2 (1 point)

2xy - 3y = 2 + 11x (1 point)

~~(2x - 3)~~ y = (2+11x)/~~(2x-3)~~ (2 points: 1 for factor and 1 for divide)

$$f^{-1}(x) = \frac{2+11x}{2x-3}$$

$$f\left(f^{-1}(x)\right) = f\left(\frac{2+11x}{2x-3}\right)$$ (1 point)

now everywhere you see an x plug in (2+11x)/(2x-3)

$$= \frac{3\left(\frac{2+11x}{2x-3}\right)+2}{2\left(\frac{2+11x}{2x-3}\right)-11}$$ (1 point)

$$= \frac{\frac{6+33x+2(2x-3)}{\cancel{2x-3}}}{\frac{4+22x-11(2x-3)}{\cancel{2x-3}}}$$ (1 point)

$$= \frac{\cancel{6}+33x+4x-\cancel{6}}{4+\cancel{22x}-\cancel{22x}+33} = \frac{37x}{37} = x$$ (1 point)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Math Problem #8 (Thomas et al, 1996; p. 489)

The U.S. population. The Museum of Science in Boston displays a running total of the U.S. population. On May 11, 1993, the total was increasing at a rate of 1 person every 14 seconds. The displayed population figure for 3:45 p.m. that day was 257,313,431.

a) Assuming exponential growth at a constant rate, find the rate constant for the population's growth (people per 365-day year).
b) At this rate, what will the U.S. population be at 3:45 p.m. Boston time on May 11, 2001?

Solution:

Phase 1:

a) Find rate constant for population growth (5 points)
b) Find population at 3:45 p.m. on May 11, 2001 (or after 8 years) (5 points)

Phase 2:

known: t = 14 seconds
Po = 257,313,431 (1 point)
P after 1 second = 257,313,432
unknown: k (1 point)

a) equation: $P = Po\ e^{kt}$ (1 point)

$P = 257,313,431e^{kt}$ (1 point)

$257,313,432 = 257,313,431\ e^{k(14)}$ (2 points)
must convert k(t) to second (1 point)
then to years and then solve for k (1 point)

b) equation: $P = 257,313,431\ e^{0.008754t}$ (2 points)

Phase 3:

a) 14 sec (1min/60 sec) (1 hr/60 min) (1 day/24 hr) (1 yr/365 days)
= 14/31,536,000 (3 points)

257,313,432/257,313,431 = e(14k/31,536,000) (2 points)

ln(257,313,432/257,313,431) = 14k/31,536,000
(31,536,000/14) ln (257,313,432/257,313,431) = k

k = 0.008754 (3 points)

b)

$P = 257{,}313{,}431\ ^{e0.008754(8)}$

$P = 2.7598 \times 10^{8}$

P = 275,980,000 (2 points)

Phase 4:

Correcting and/or verifying phase 1 (2 points)
Correcting and/or verifying phase 2 (3 points)
Correcting and/or verifying phase 3 (5 points)

Appendix A.3 Supplementary Questionnaires

Appendix A.3 contains the questionnaires used to collect supplemental data for the tutoring process. Appendix A.3.1 contains the background questionnaire administered prior to the start of the trials. Appendices A.3.2 - A.3.11 contain the questionnaires the subjects complete after each phase and after the trial was complete. Appendices A.3.12 - A.3.13 contains the questionnaires for the tutor to complete after each trial. Appendix A.3.14 contains the ranked order questionnaire administered five times, once for each phase and once for the overall tutoring process after the subjects completed all of their trials.

Appendix A.3.1 Background

Background Information Questionnaire

Date_____

Please answer the following questions:

1. Please circle all of the following math courses you have completed while in high school and the grade you earned in each course (if you can remember it):

Course	**Grade**
Trigonometry	_____
Pre-calculus	_____
Geometry	_____
Calculus	_____
Advanced Algebra	_____
Advanced Placement Calculus	_____
other (please specify):	
_____	_____

2. Have you ever participated in tutoring?

Yes No

If your answer is yes were you the tutor, the person getting tutored, or both?_____

3. Did you have computer experience prior to attending ASPIRE '97? (please circle response)

Yes No

If you answered No to question number 3, please skip to question 4.

3a. Please circle the response that most closely reflects the amount of time you have spent using computers:

less than 1 year between 1 and 2 years more than 2 years

3b. List how you have used the computer (for example, programming, word processing, Internet surfing, etc.)

4. Have you ever used email?

Yes No

5. Have you ever used a chatroom?

Yes No

6. Have you ever participated in video teleconferencing?

Yes No

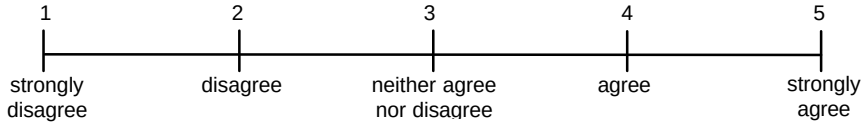
Appendix A.3.2 Phase 1 – No Feedback Cue

Phase I: Understand the Problem

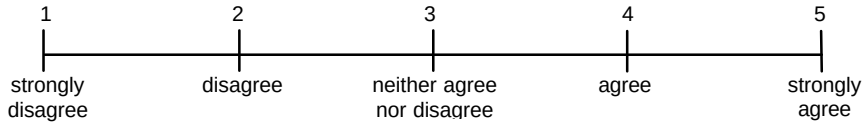
Communication Method: _____

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 1 of the problem solving process (Understand the Problem).*

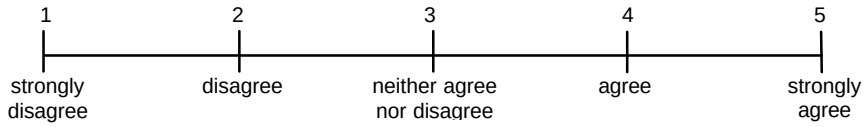
1. There is no doubt that the problem statement I have developed is correct:



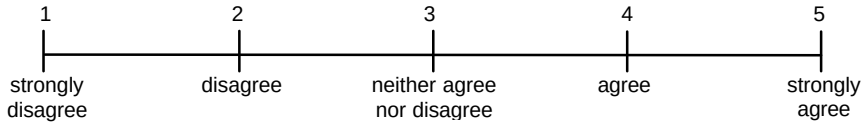
2. I completely understood the problem statement I developed:



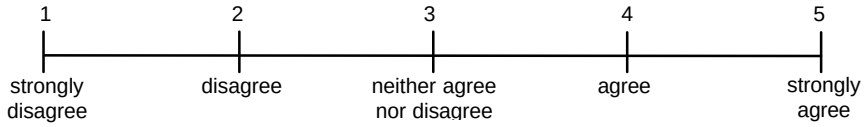
3. The interaction between the tutor and myself was outstanding with little conflict:



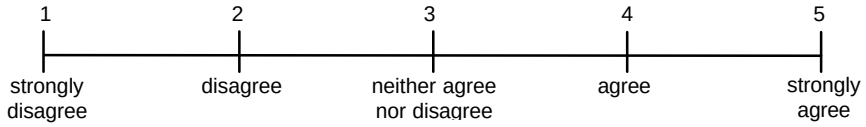
4. The communication method I used was an easy way to work with the tutor:



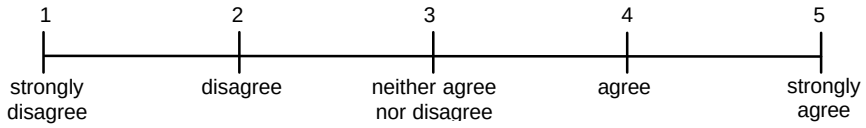
5. The communication method I used saved me time when I worked with the tutor:



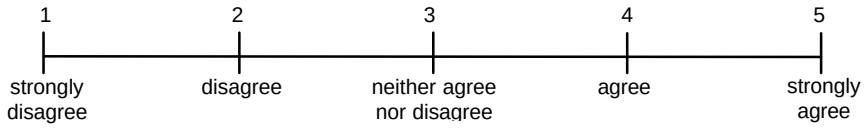
6. The communication method I used was very effective for working with the tutor:



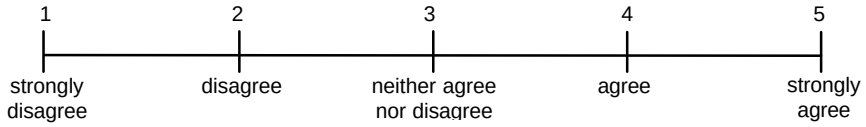
7. I was extremely satisfied with the communication method I used to work with the tutor:



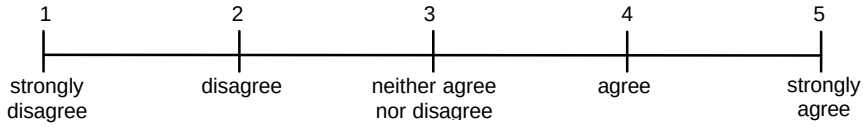
8. The tutor completely answered all of the questions I asked:



9. I was very comfortable working with the tutor:



10. Overall, I was completely satisfied with the entire tutoring process for developing the problem statement:



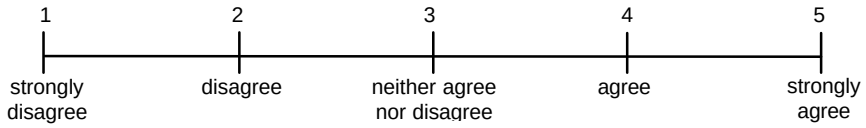
Please make any comments you have about what occurred in phase 1 (understand the problem) in the space below:

Phase I: Understand the Problem

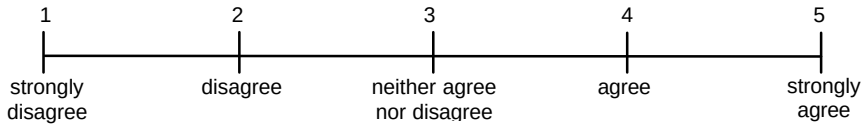
Communication Method: _____
with Feedback Cue

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 1 of the problem solving process (Understand the Problem).*

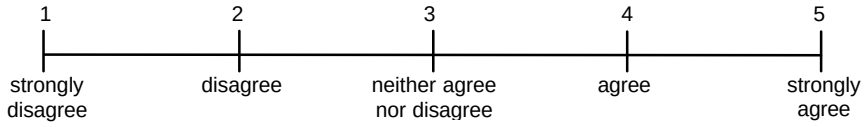
1. There is no doubt that the problem statement I have developed is correct:



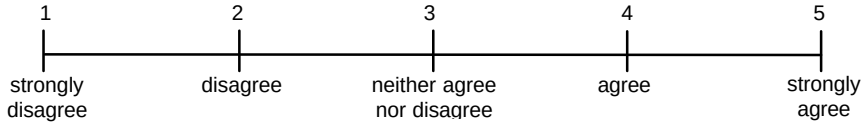
2. I completely understood the problem statement I developed:



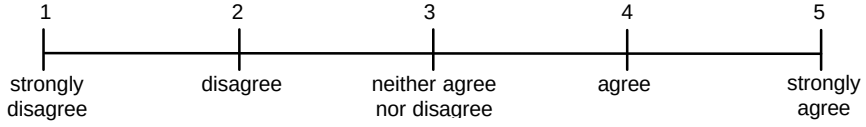
3. The interaction between the tutor and myself was outstanding with little conflict:



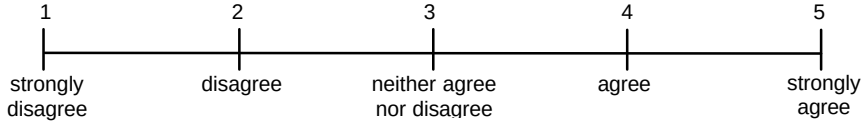
4. The communication method I used was an easy way to work with the tutor:



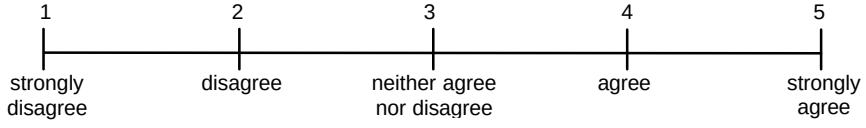
5. The communication method I used saved me time when I worked with the tutor:



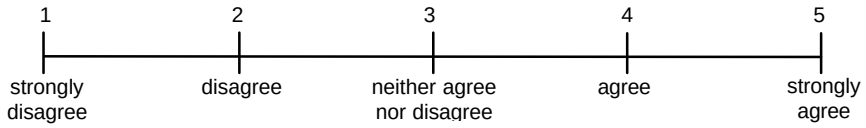
6. The communication method I used was very effective for working with the tutor:



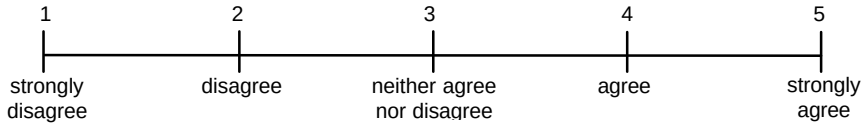
7. I was extremely satisfied with the communication method I used to work with the tutor:



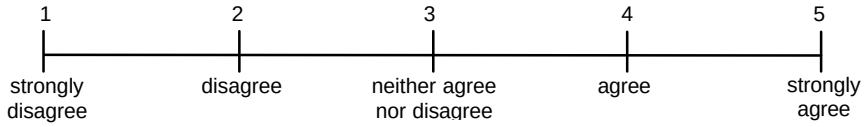
8. The feedback cue was an easy way to let the tutor know my level of understanding:



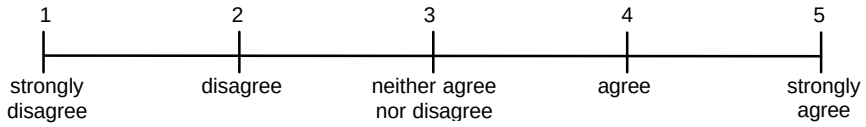
9. The feedback cue saved me time because the tutor knew my level of understanding at all times:



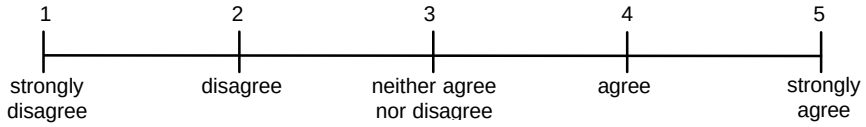
10. The feedback cue was a very effective method for letting the tutor know my level of understanding:



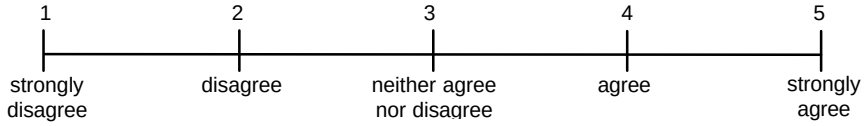
11. I was extremely satisfied using the feedback cue while generating the problem statement:



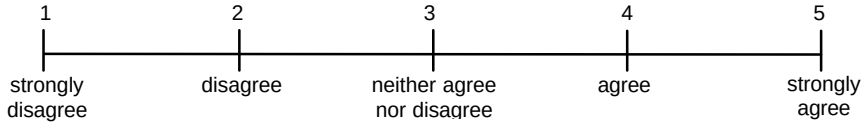
12. The tutor completely answered all of the questions I asked:



13. I was very comfortable working with the tutor:



14. Overall, I was completely satisfied with the entire tutoring process for developing the problem statement:



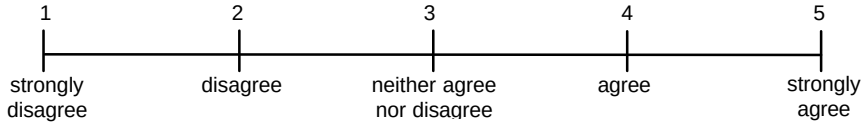
Please make any comments you have about what occurred in phase 1 (understand the problem) in the space below:

Phase II: Plan the Approach to the Solution

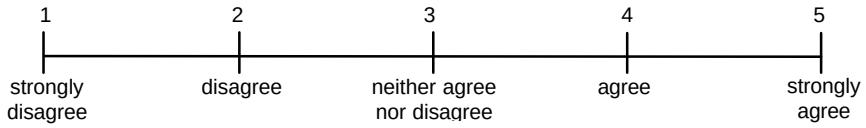
Communication Method: _____

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 2 of the problem solving process (Plan the Approach to the Solution).*

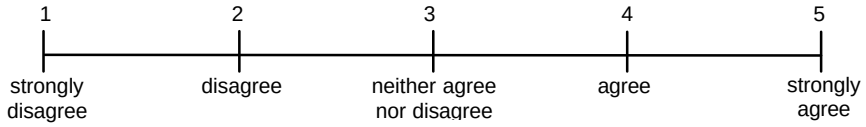
1. There is no doubt that the plan I have developed is correct:



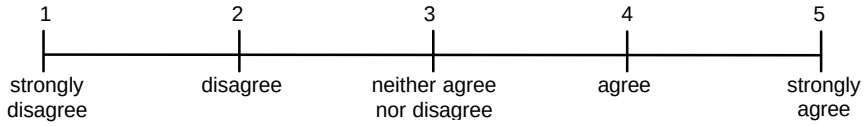
2. I completely understood the plan I developed:



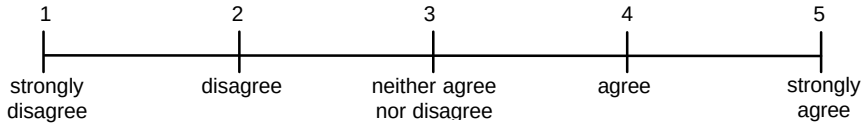
3. The interaction between the tutor and myself was outstanding with little conflict:



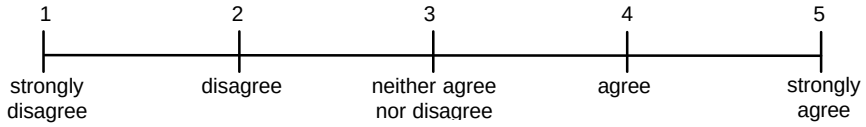
4. The communication method I used was an easy way to work with the tutor:



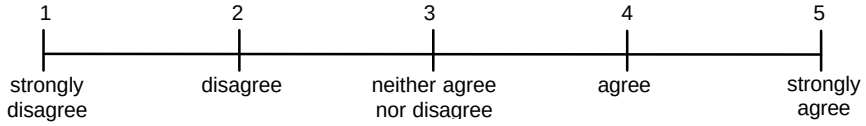
5. The communication method I used saved me time when I worked with to the tutor:



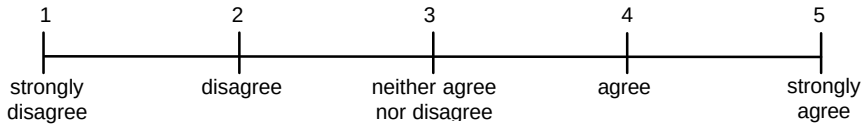
6. The communication method I used was very effective for working with the tutor:



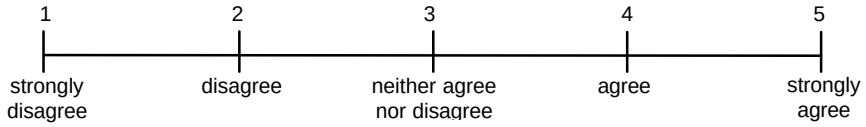
7. I was extremely satisfied with the communication method I used to work with the tutor:



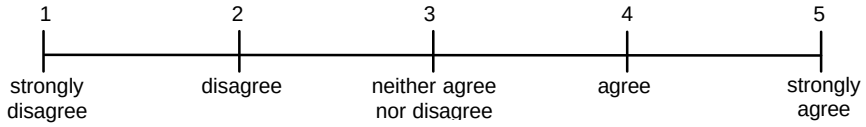
8. The tutor completely answered all of the questions I asked:



9. I was very comfortable working with the tutor:



10. Overall, I was completely satisfied with the entire tutoring process for planning the solution:



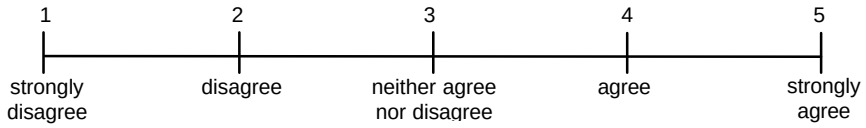
Please make any comments you have about what occurred in phase 2 (plan the solution) in the space below:

Phase II: Plan the Approach to the Solution

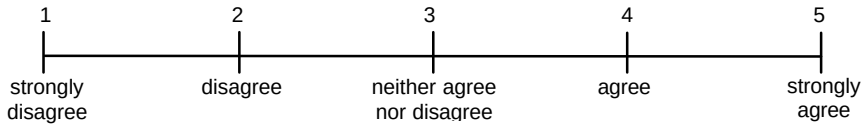
Communication Method:_____
with Feedback Cue

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 2 of the problem solving process (Plan the Approach to the Solution).*

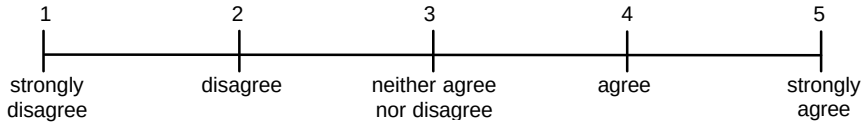
1. There is no doubt that the plan I have developed is correct:



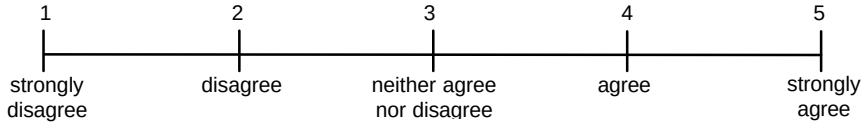
2. I completely understood the plan I developed:



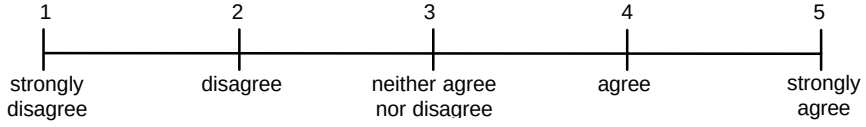
3. The interaction the tutor and myself was outstanding with little conflict:



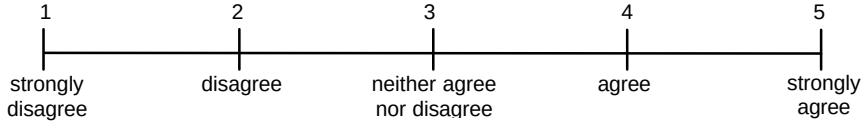
4. The communication method I used was an easy way to work with the tutor:



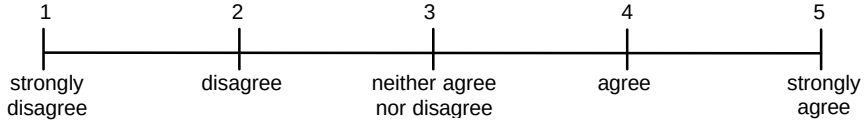
5. The communication method I used saved me time when I worked with the tutor:



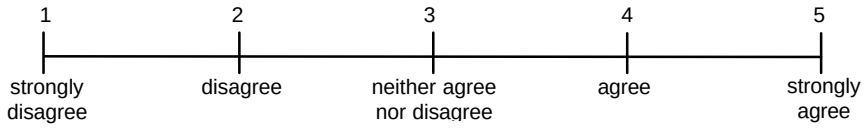
6. The communication method I used was very effective for working with the tutor:



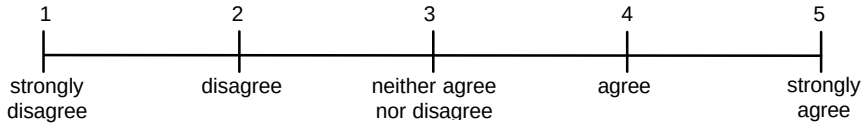
7. I was extremely satisfied with the communication method I used to work with the tutor:



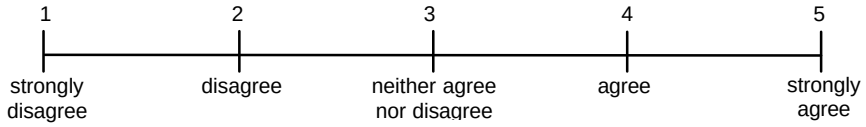
8. The feedback cue was an easy way to let the tutor know my level of understanding:



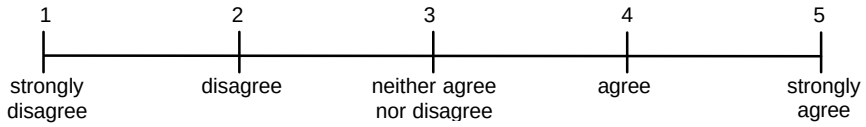
9. The feedback cue saved me time because the tutor knew my level of understanding at all times:



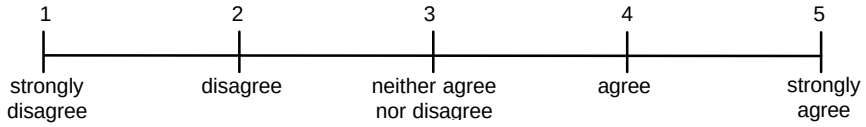
10. The feedback cue was a very effective method for letting the tutor know my level of understanding:



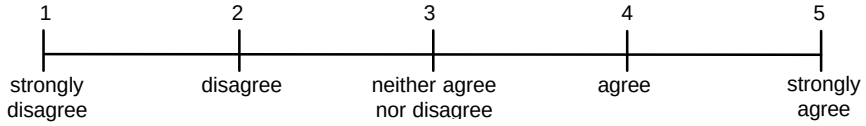
11. I was extremely satisfied using the feedback cue while generating the plan:



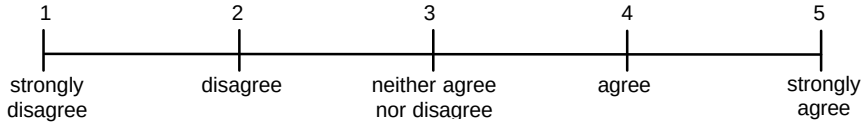
12. The tutor completely answered all of the questions I asked:



13. I was very comfortable working with the tutor:



14. Overall, I was completely satisfied with the entire tutoring process for planning the solution:



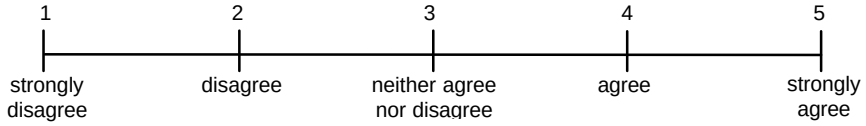
Please make any comments you have about what occurred in phase 2 (plan the solution) in the space below:

Phase III: Solve the Problem

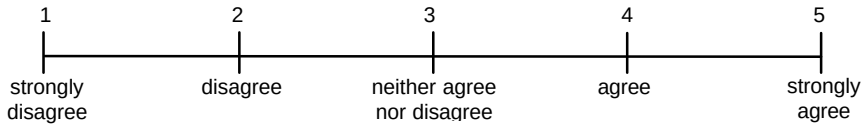
Communication Method: _____

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 3 of the problem solving process (Solve the Problem).*

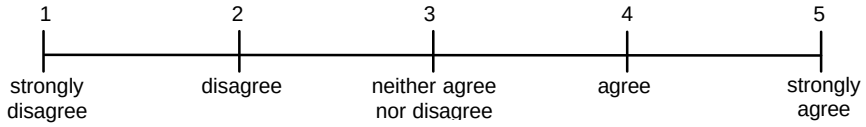
1. There is no doubt that the solution I found is correct:



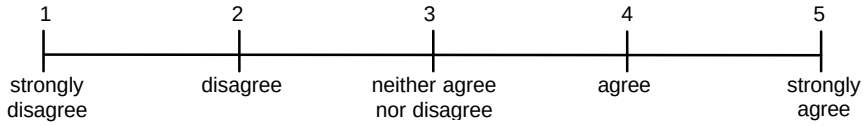
2. I completely understood the solution to the math problem:



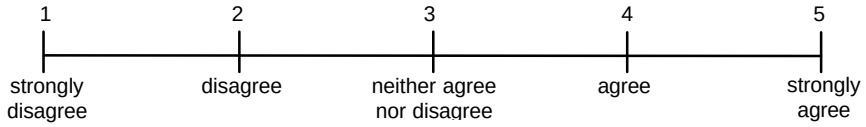
3. The interaction between the tutor and myself was outstanding with little conflict:



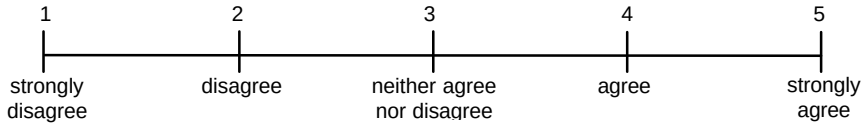
4. The communication method I used was an easy way to work with the tutor:



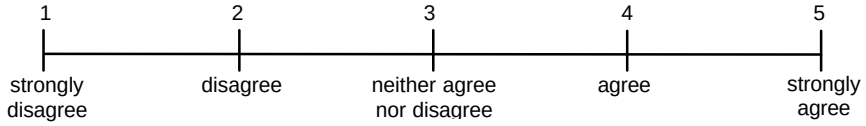
5. The communication method I used saved me time when I worked with the tutor:



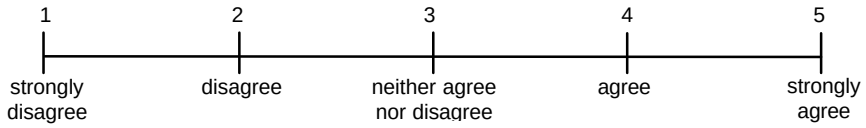
6. The communication method I used was very effective for working with the tutor:



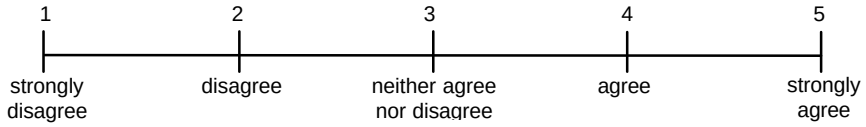
7. I was extremely satisfied with the communication method I used to work with the tutor:



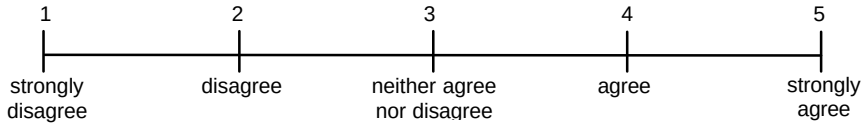
8. The tutor completely answered all of the questions I asked:



9. I was very comfortable working with the tutor:



10. Overall, I was completely satisfied with the entire tutoring process for solving the problem:



Please make any comments you have about what occurred in phase 3 (solve the problem) in the space below:

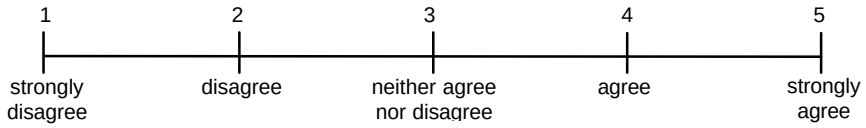
Appendix A.3.7 Phase 3 -- Feedback Cue

Phase III: Solve the Problem

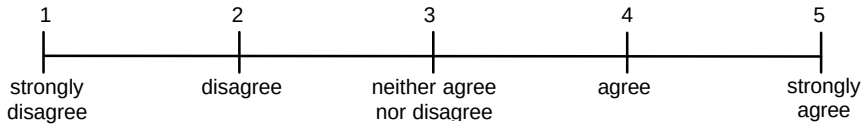
Communication Method:_____
with Feedback Cue

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 3 of the problem solving process (Solve the Problem).*

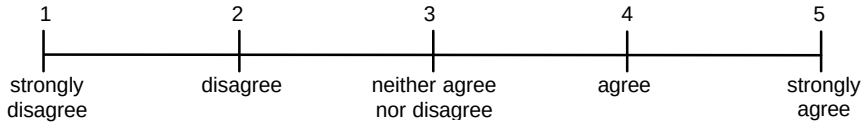
1. There is no doubt that the solution I have found is correct:



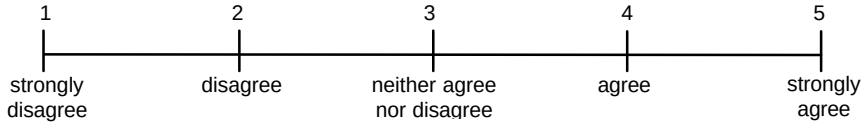
2. I completely understood my solution to the math problem:



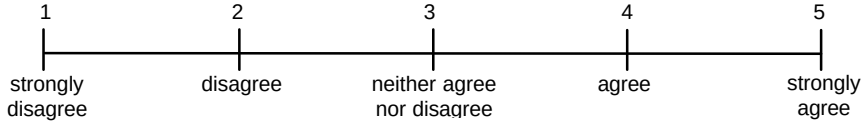
3. The interaction between the tutor and myself was outstanding with little conflict:



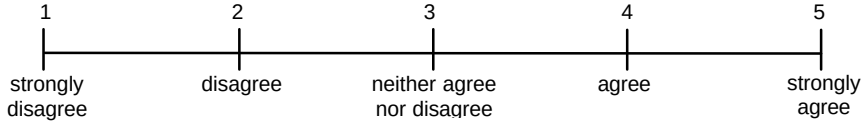
4. The communication method I used was an easy way to work with the tutor:



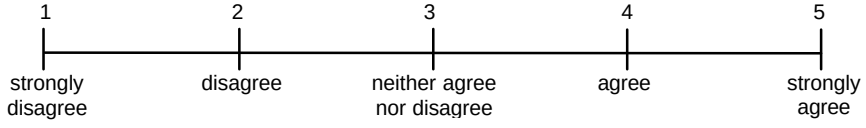
5. The communication method I used saved me time when I worked with the tutor:



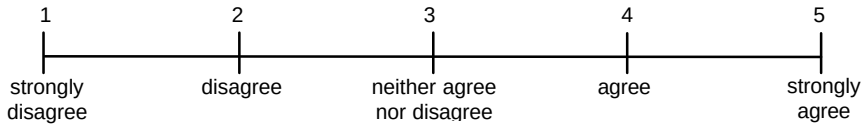
6. The communication method I used was very effective for working with the tutor:



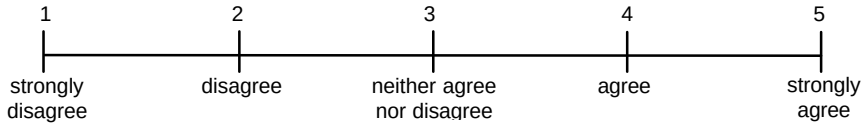
7. I was extremely satisfied with the communication method I used to work with the tutor:



8. The feedback cue was an easy way to let the tutor know my level of understanding:



9. The feedback cue saved me time because the tutor knew my level of understanding at all times:



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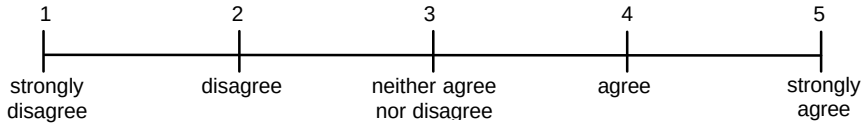
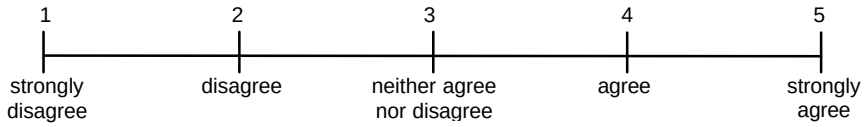
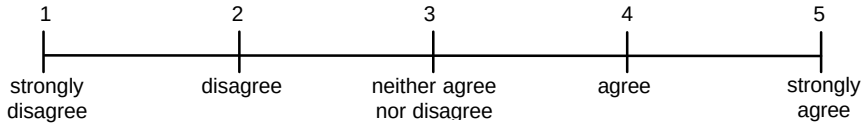


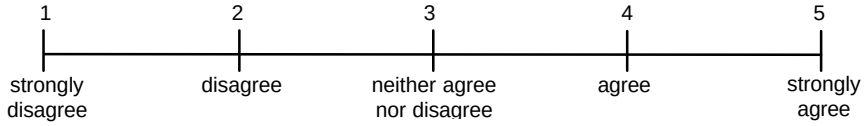
11. I was extremely satisfied using the feedback cue while generating the solution:



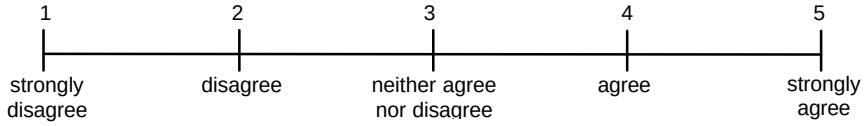
12. The tutor completely answered all of the questions I asked:



13. I was very comfortable working with the tutor:



14. Overall, I was completely satisfied with the entire tutoring process for solving the problem:



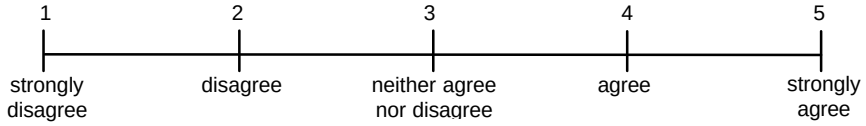
Please make any comments you have about what occurred in phase 3 (solve the problem) in the space below:

Phase IV: Review the Problem Solution

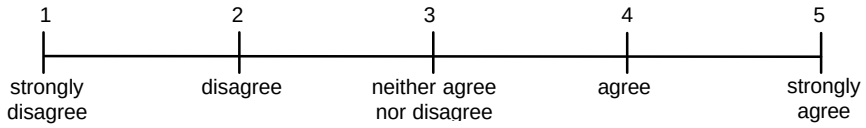
Communication Method: _____

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 4 of the problem solving process (Review the Problem Solution).*

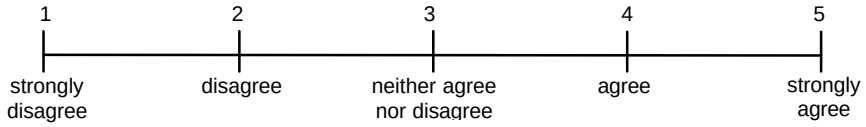
1. There is no doubt that the problem review I completed is correct:



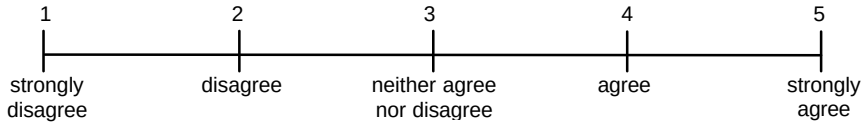
2. I completely understood the review of the math problem:



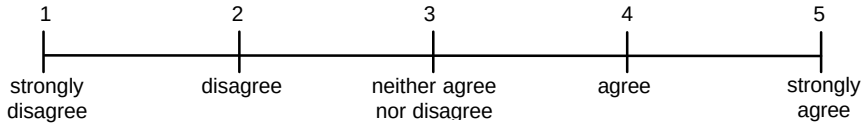
3. The interaction between the tutor and myself was outstanding with little conflict:



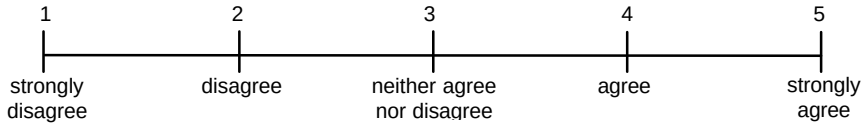
4. The communication method I used was an easy way to work with the tutor:



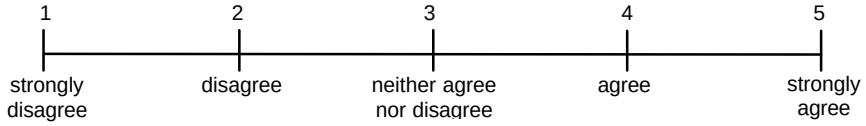
5. The communication method I used saved me time when I worked with the tutor:



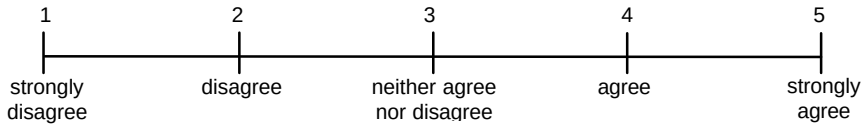
6. The communication method I used was very effective for working with the tutor:



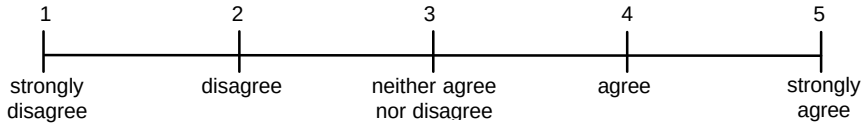
7. I was extremely satisfied with the communication method I used to work with the tutor:



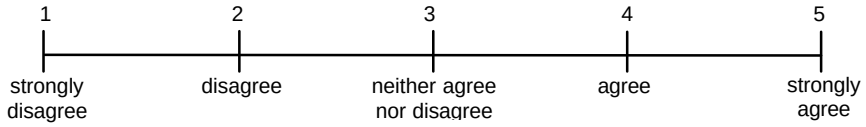
8. The tutor completely answered all of the questions I asked:



9. I was very comfortable working with the tutor:



10. Overall, I was completely satisfied with the entire tutoring process for reviewing the problem solution:



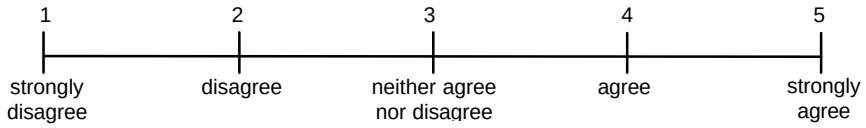
Please make any comments you have about what occurred in phase 4 (review the problem solution) in the space below:

Phase IV: Review the Problem Solution

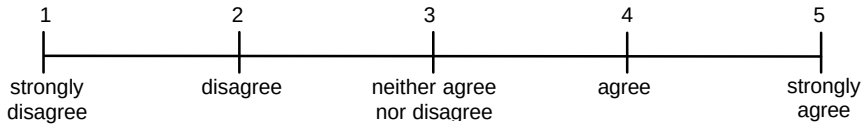
Communication Method:_____
with Feedback Cue

Please circle the response of the choice which most closely reflects your feelings. *These questions are only about activities you have been involved with for phase 4 of the problem solving process (Review the Problem Solution).*

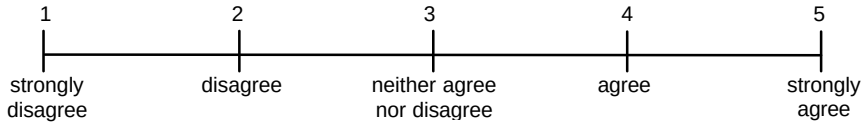
1. There is no doubt that the problem review I completed is correct:



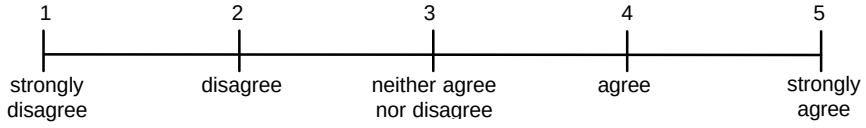
2. I completely understood the review of the math problem:



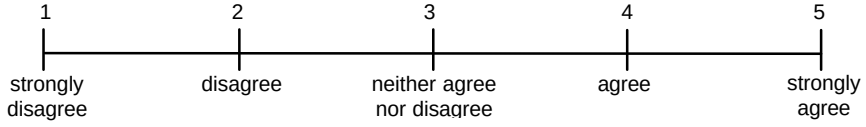
3. The interaction between the tutor and myself was outstanding with little conflict:



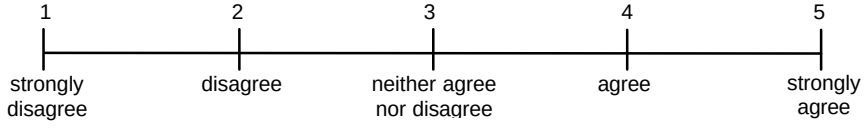
4. The communication method I used was an easy way to work with the tutor:



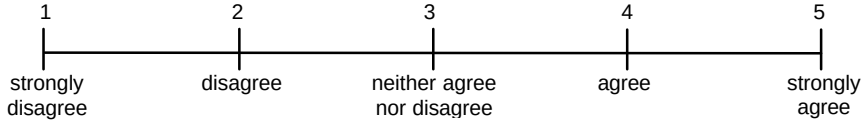
5. The communication method I used saved me time when I worked with the tutor:



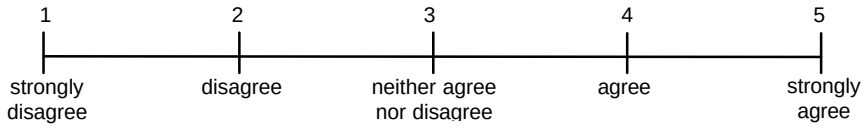
6. The communication method I used was very effective for working with the tutor:



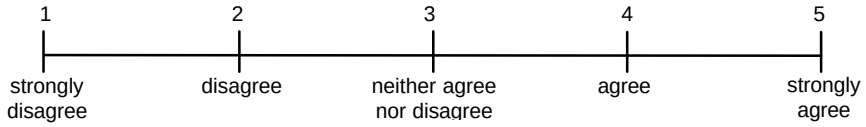
7. I was extremely satisfied with the communication method I used to work with the tutor:



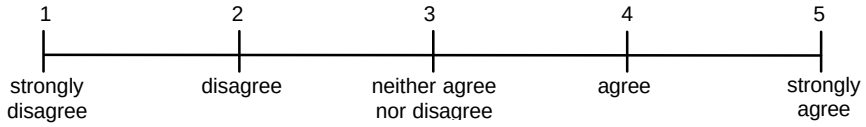
8. The feedback cue was an easy way to let the tutor know my level of understanding:



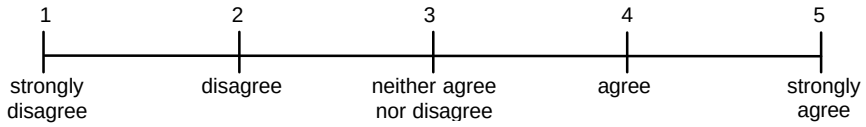
9. The feedback cue saved me time because the tutor knew my level of understanding at all times:



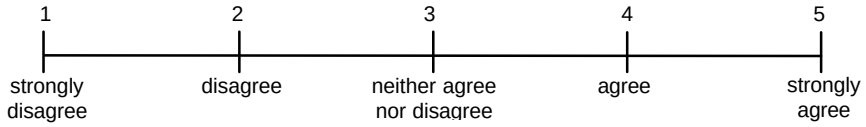
10. The feedback cue was a very effective method for letting the tutor know my level of understanding:



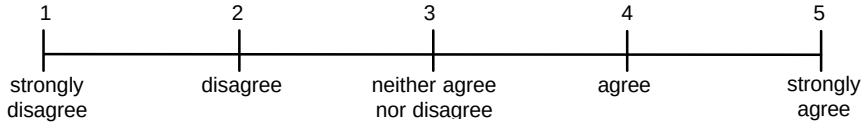
11. I was extremely satisfied using the feedback cue while reviewing the problem solution:



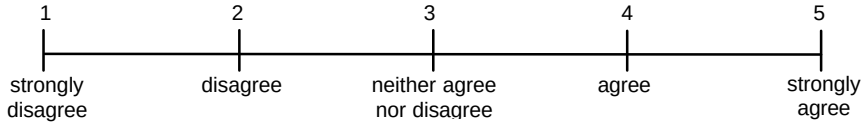
12. The tutor completely answered all of the questions I asked:



13. I was very comfortable working with the tutor:



14. Overall, I was completely satisfied with the entire tutoring process for reviewing the problem solution:



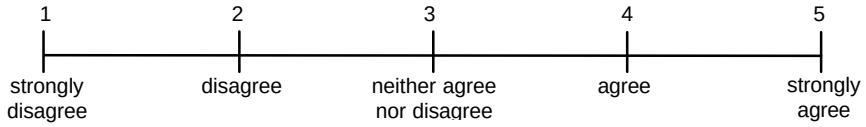
Please make any comments you have about what occurred in phase 4 (review the problem solution) in the space below:

Overall

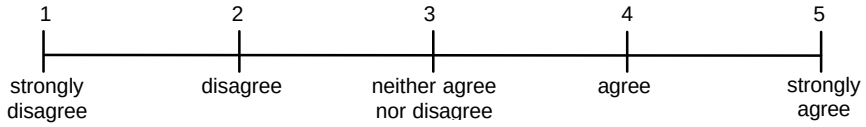
Communication Method: _____

Please circle the response of the choice which most closely reflects your feelings. *These questions are about the **overall** tutoring process.*

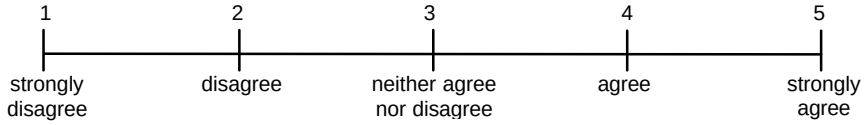
1. There is no doubt that the overall solution I developed is correct:



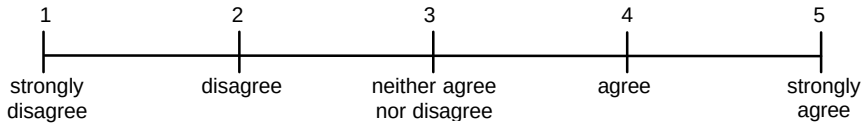
2. I completely understood the concepts covered in the math problem:



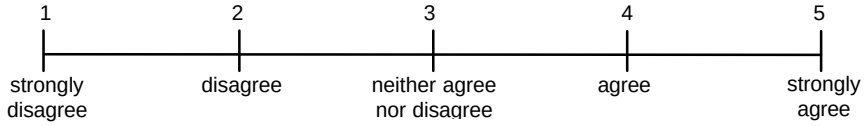
3. The interaction between the tutor and myself was outstanding with little conflict:



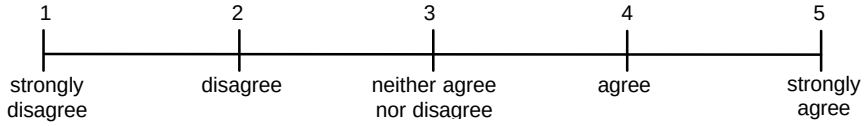
4. Overall, the communication method I used was an easy way to work with the tutor:



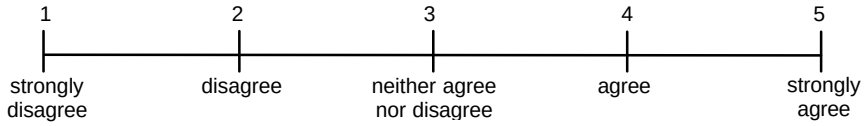
5. Overall, the communication method I used saved me time when I worked with the tutor:



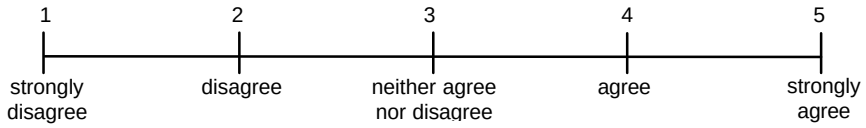
6. Overall, the communication method I used was very effective for working with the tutor:



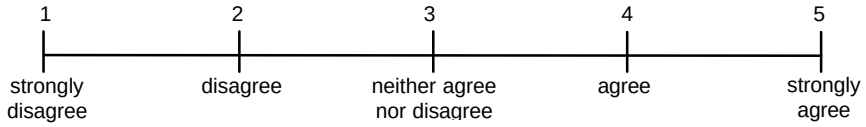
7. Overall, I was extremely satisfied with the communication method I used to work with the tutor:



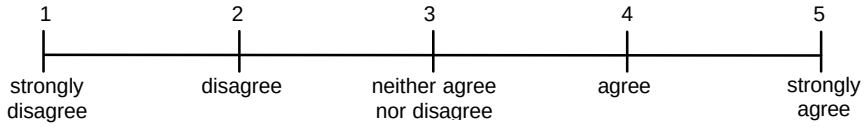
8. I was extremely satisfied with the problem solving approach we took to solving the math problem:



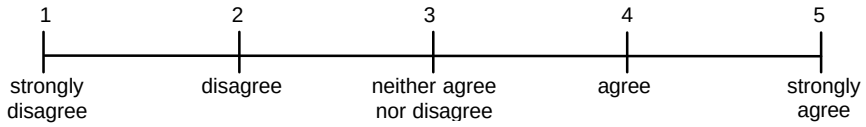
9. The tutor completely answered all of the questions I asked:



10. I was very comfortable working with the tutor:



11. Overall, I was completely satisfied with the entire tutoring process:



Please describe what you think about using this communication method for tutoring:

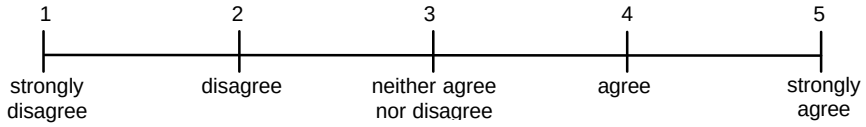
Please describe what you think about using the problem solving process for tutoring:

Overall

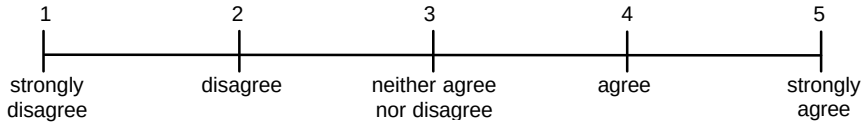
Communication Method: _____
with Feedback Cue

Please circle the response of the choice which most closely reflects your feelings. *These questions are about the **overall** tutoring process.*

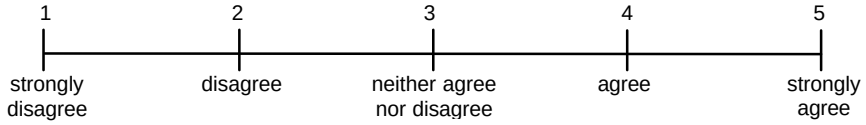
1. There is no doubt that the overall solution I developed is correct:



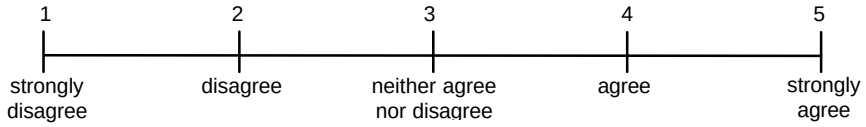
2. I completely understood the concepts covered in the math problem:



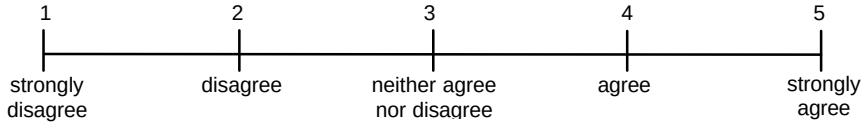
3. There was little conflict between the tutor and myself:



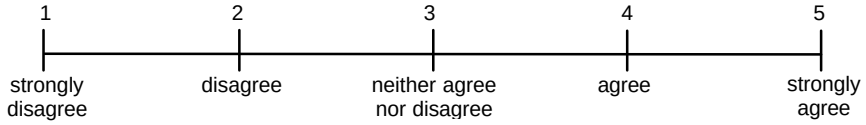
4. Overall, the communication method I used was an easy way to work with the tutor:



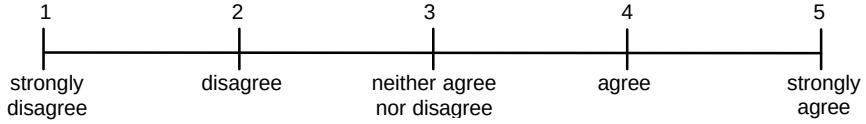
5. Overall, the communication method I used saved me time when I worked with the tutor:



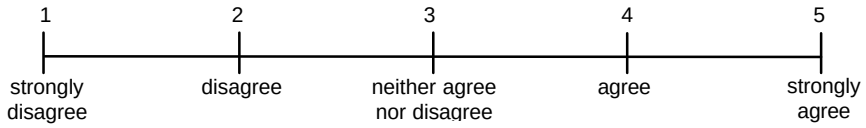
6. Overall, the communication method I used was very effective for working with the tutor:



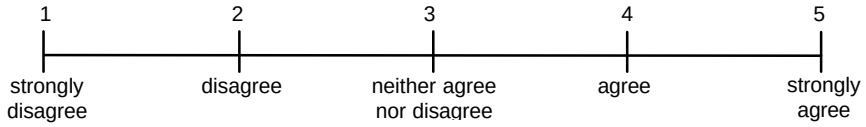
7. Overall, I was extremely satisfied with the communication method I used to work with the tutor:



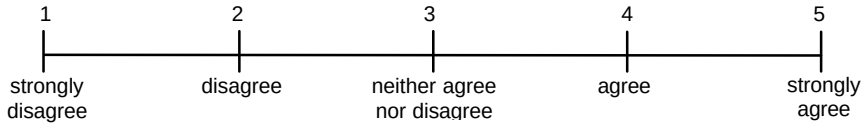
8. Overall, the feedback cue was an easy way to let the tutor know my level of understanding:



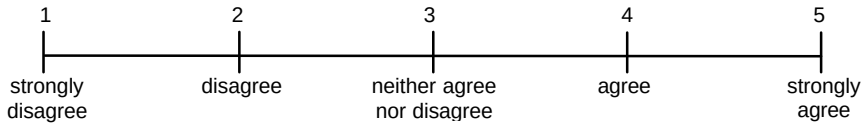
9. Overall, the feedback cue saved me time when because the tutor knew my level of understanding at all times:



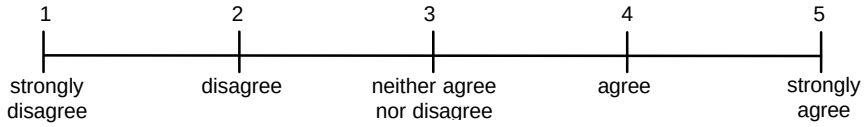
10. Overall, the feedback cue was a very effective method for letting the tutor know my level of understanding:



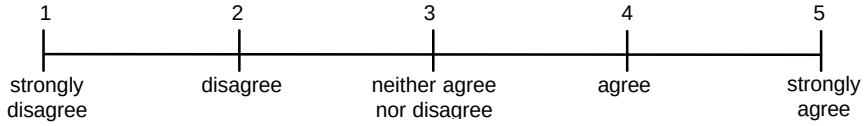
11. Overall, I was extremely satisfied using the feedback cue while working on this math problem:



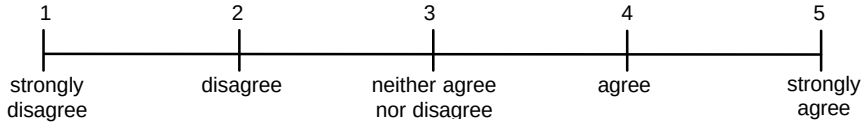
12. I was extremely satisfied with the problem solving approach we took to solving the math problem:



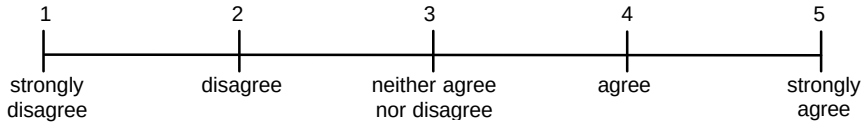
13. The tutor completely answered all of the questions I asked:



14. I was very comfortable working with the tutor:



15. Overall, I was completely satisfied with the entire tutoring process:



Please describe what you think about using this communication method for tutoring:

Please describe what you think about the feedback cue you used today for tutoring:

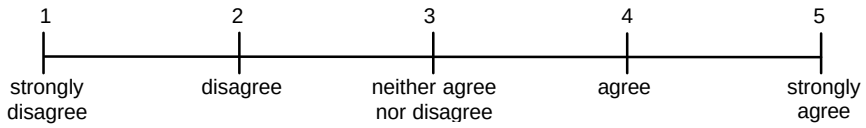
Please describe what you think about using the problem solving process for tutoring:

Appendix A.3.12 Tutor -- No Feedback Cue

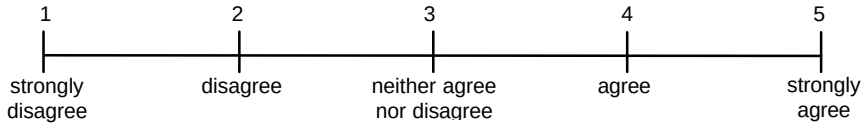
Tutor

Please circle the response of the choice which most closely reflects your feelings.

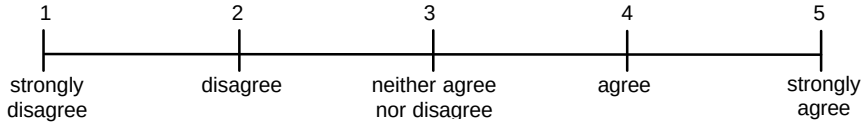
1. The student completely understood the problem we worked on:



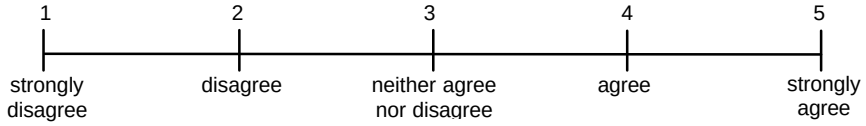
2. The communication method I used was an easy way to work with the student:



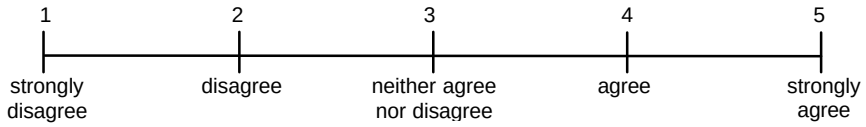
3. The communication method I used save me time when I worked with the student:



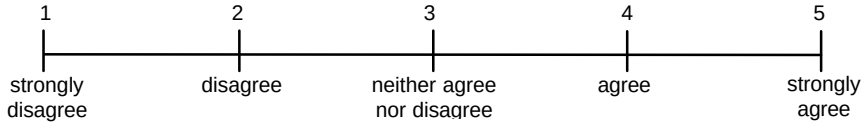
4. The communication method I used was very effective for working with the student:



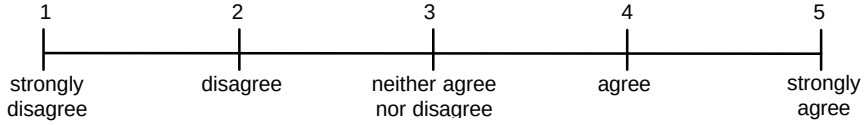
5. I was extremely satisfied with the communication method I used to work with the student:



6. I completely answered all of the questions the student asked me:



7. Overall, I was completely satisfied with the entire tutoring process for solving the math problem:



Please describe what you think about the communication method you used today for tutoring: (use back for more room)

Please describe what you think about the problem solving approach: (use back for more room)

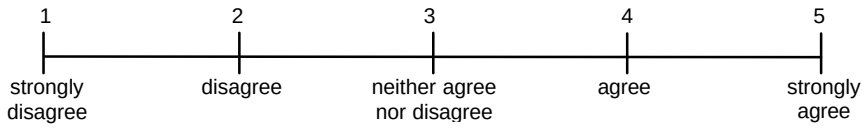
Other comments: (use back for more room)

Appendix A.3.13 Tutor -- Feedback Cue

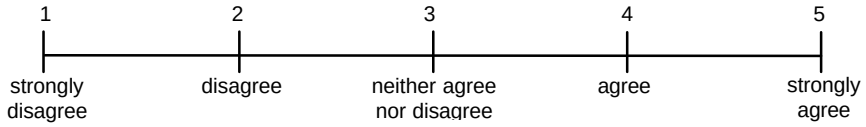
Tutor

Please circle the response of the choice which most closely reflects your feelings.

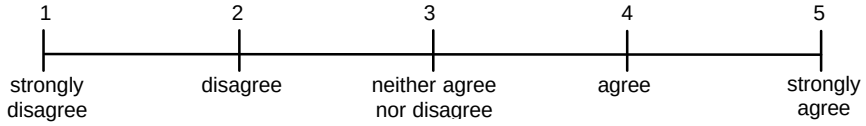
1. The student completely understood the problem we worked on:



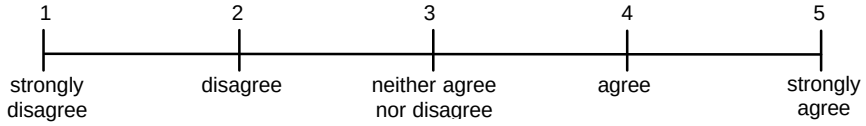
2. The communication method I used was an easy way to work with the student:



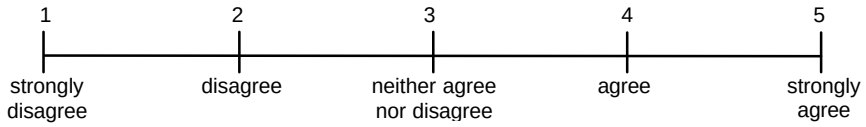
3. The feedback cue was an easy way to me know the student's level of understanding:



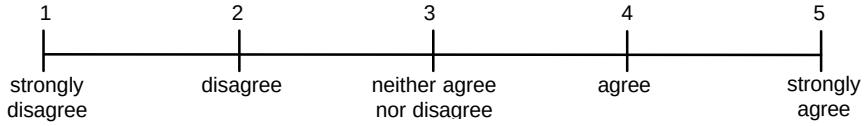
4. The communication method I used save me time when I worked with the student:



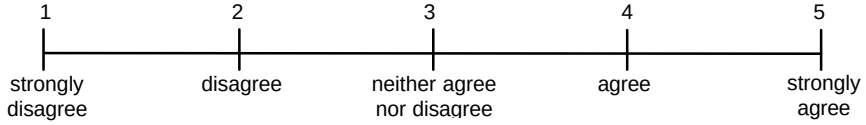
5. The feedback cue saved me time by letting me know the student's level of understanding:



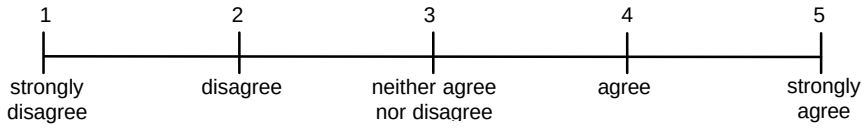
6. The communication method I used was very effective for working with the student:



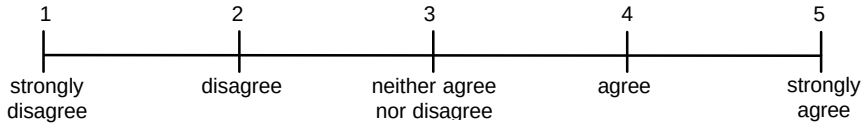
7. The feedback cue was a very effective method for letting me know the student's level of understanding:



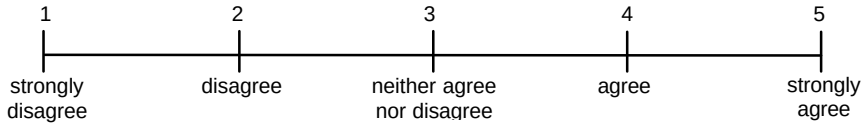
8. I was extremely satisfied with the communication method I used to work with the student:



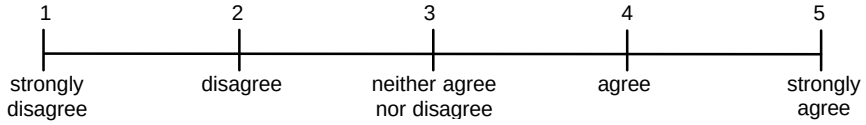
9. I was extremely satisfied with the feedback cue for letting me know the student's level of understanding:



10. I completely answered all of the questions the student asked me:



11. Overall, I was completely satisfied with the entire tutoring process for solving the math problem:



Please describe what you think about the communication method you used today for tutoring:

Please describe what you think about the feedback cue you used today to tutoring:

Please describe what you think about the problem solving approach:

Other comments:

Appendix A.3.14 Rank Order

For Phase ___ of the tutoring process, rank order the tutoring communication set ups in the order you preferred using them based on the statements below. (**1 is the highest, for example, the one you most preferred, and 8 is the lowest, for example, the one you least preferred**).

The communication condition that made working with the tutor the easiest was:

___face to face	___email	___chat	___video teleconferencing
___face to face & feedback cue	___email & feedback cue	___chat & feedback cue	___video teleconferencing & feedback cue

The communication condition that saved me the most time was:

___face to face	___email	___chat	___video teleconferencing
___face to face & feedback cue	___email & feedback cue	___chat & feedback cue	___video teleconferencing & feedback cue

The most effective communication condition was:

___face to face	___email	___chat	___video teleconferencing
___face to face & feedback cue	___email & feedback cue	___chat & feedback cue	___video teleconferencing & feedback cue

The communication condition I was most satisfied with was:

___face to face	___email	___chat	___video teleconferencing
___face to face & feedback cue	___email & feedback cue	___chat & feedback cue	___video teleconferencing & feedback cue

The communication condition in which I was most comfortable working with the tutor was:

___face to face	___email	___chat	___video teleconferencing
___face to face & feedback cue	___email & feedback cue	___chat & feedback cue	___video teleconferencing & feedback cue

Appendix A.4 Tutor Script

Tutor Script

Instructions to Tutor: Read (or type) the regular font words to the students word for word. The italicized sections are instructions and notes to the tutor. Don't read these out loud. Note – if at anytime the students are unable to figure out what to do, give them examples without actually solving the problem for them. Or give them a starting point, e.g., you might approach it this way, or this way. Also, make sure they are recording all work on the worksheets provided to them.

Introduction: I am going to guide you through four steps of a problem solving process in order to solve the math problem in front of you. Please do not work ahead of my instructions. We have one hour to solve this problem. You may ask me any questions at any time. And if you don't understand something, let me know. Let's get started. Read the problem in front of you. Let me know when you have finished reading.

Wait to let the students read the problem.

Phase 1 – Understand the Problem:

The first step is to understand the problem. Determine what the problem is asking for and put it in your own words. Use a diagram (picture) if you need to. Let me know if you have any questions. Tell me when you have a problem statement? (*Wait for them to come up with a statement. Make sure they are writing it down on the solution sheet.*)

If they are having trouble with the problem statement, ask them questions or give examples that might help them. If the problem statement is wrong, don't make them change their problem statement – in phase 4 you will go over the problem completely. Answer their questions. If they try to start solving the problem at this point, explain that they will get to specifics in the next step – this step is for general understanding. Once they have a problem statement they are in agreement with, you may go on.

Please fill out the questionnaire for phase 1, understanding the problem, and tell me when you are finished.

Phase 2: Now, we will develop an approach for solving this problem. Plan how you will solve this problem -- Do not actually solve the problem by plugging numbers. First, you need to determine what you know from the problem and what you need to know. Second, list the equations you need in order to solve this problem. Third, using words and symbols, describe the steps you will need to take in order to come up with a solution. If you don't understand something, don't hesitate to ask me questions. Let me know when you have a plan.

Ask the students questions when appropriate to help them come up with an approach to solving the problem. Answer their questions. If they start to actually plug numbers into the equations explain that they will get to solve the problem in the next step – this step is for planning and information gathering. When they feel they have a reasonable plan, you may go to phase 3.

Please fill out the questionnaire for phase 2, planning the problem solution, and tell me when you are finished.

Phase 3: Now you will solve the problem following the plan you've just created. When you have finished give me your final answer. Don't forget to ask me questions if you get stuck.

Wait while students solve the problem.

Please fill out the questionnaire for phase 3, solving the problem.

Phase 4:

In this phase, you will help them find mistakes. Even if their solution is correct go through each step. This is a very individualized phase.

Now, let's review what you've done. We are going to go through each step and you are going to tell me what you did and why. Let's start with your problem statement. Please read through your interpretation of the problem statement and tell me what you think about it. Are you happy with it, or do you think changes are needed?

If they want to make changes find out what they would change and why. If they change their statement ask them questions about why they originally interpreted it the way they did.

Now look at your plan that includes knowns, unknowns, and equations. Are these still appropriate? What would you change? (*wait while they tell you*) Why would you make that change? *There may be more than one thing to change so you may need to go through these questions several time, e.g., are there any other changes? If there are errors question them about specific problems you see in this section. Then go through the steps for their problem solution. If there are errors in the plan, question them on why they listed that particular step. Point out conceptual errors and explain the correct method.*

Did you follow this plan? *If they did not, then ask them:* What did you change and why.

If they have a correct plan but incorrect answer go through the math with them. If you see math errors point out the places they might want to rework or ask them why they did something a particular way. If they have a correct solution go on to the questions.

Could you have worked this problem a different way?

If they answer no and there is more than one way to work this problem, give the student hints to see if they can come up with it. But don't rework the problem. If they answer yes, ask them the following question:

How else could you have solved this problem?

Do you have any questions about what we have done?

Wait for response, then answer questions if any.

Is there anything you don't understand that you want me to explain?

Wait for response, then answer questions if any.

Thank you for participating today. Your session is now over. But you still have several questionnaires to fill out and then you are finished for today.

Appendix A.5 Informed Consent

The document that was submitted to the Institutional Review Board (IRB) had the subjects working in groups for tutoring. Because of a lack of subjects that met the age requirement (minimum of 18 years old), the consent form was changed to reflect the tutoring would be one-on-one tutoring. The researcher met with the Chairperson of the Institutional Review Board to ensure this change did not violate the approval agreement.

Informed Consent for Participants of Research Study

Title of Project: Human-Centered Communication Technologies to Enhance Tutoring

Investigators: Paige E. Smith, Dr. Brian M. Kleiner

I. The Purpose of this Research

The purpose of this research is 1) to determine if communication technology can improve tutoring, 2) determine if feedback cues can improve tutoring, 3) explore the impact of the problem solving approach on tutoring, and 4) to research several different communication platforms that may be amenable to tutoring.

In this research, we will look at face-to-face, email, chatroom, and video teleconferencing as methods for communicating during tutoring sessions. Another issue we are looking at is the use of feedback cues. A feedback cue is a nonverbal method for letting the tutor know how well you understand the material being covered. When you have access to the feedback cue, you will be letting the tutor know how well you understand the information in a continuous manner. The tutor should adjust his level of explanation based on your feedback.

A problem solving approach to tutoring is used in this research. This means the tutor will lead you through a four phased approach to solving a math problem. The phases include 1) understanding the problem, 2) planning the approach to the problem, 3) solving the problem, and 4) reviewing the problem solution.

Through this research, we are looking for ways to improve tutoring and at the same time, make tutoring more accessible to students.

II. Procedures

This research will take place in room 104 in McBryde Hall. Under the guidance of a tutor, you will solve a math problem. Each session will last one hour. You are encouraged to work as quickly as possible. However, it is more important that you understand the content in the problem you are solving than it is for you to actually complete the problem. Over the five weeks you are here at Virginia Tech, you will have the opportunity to solve eight math problems.

Overall you will participate in eight different tutoring configurations. The eight configurations for tutoring are face-to-face with feedback cues, email with feedback cues, chatroom with feedback cues, video teleconferencing with feedback cues, face-to-face without feedback cues, email without feedback cues, chatrooms without feedback cues, and video teleconferencing without feedback cues.

You will fill out a background questionnaire prior to the start of this research to gather information about your math and computer experience. In addition, you will complete a questionnaire after each problem solving phase has been completed. And after you have participated in the last trial, you will fill out a summary questionnaire.

III. Risks

The risks associated with this research are minimal, that is, no greater than those associated with daily life.

IV. Benefits of this Project

By participating in this research, you will receive tutoring in mathematics. In addition, you will have a chance to practice the math skills you have been learning in your mathematics class. You will also practice using problem solving skills. In addition, you will be exposed to a variety of communication technologies.

One of the goals of this research is to find the best type of communication technology for tutoring. The results of this study will be used by the College of Engineering's Student Assistance Center to help make tutoring more accessible to students.

No promise or guarantee of benefits can been made to encourage you to participate in this research.

V. Extent of Anonymity and Confidentiality

Information collected in this research will be kept strictly confidential. You will not be identified except to the researchers involved in the execution of this study.

A video tape of each session will be made in order to collect data that cannot be collected during each trial. Only the principal investigators will have access to these video tape recordings. The information contained in the tapes will be destroyed no later than one year after this research is completed.

VI. Compensation

No monetary compensation will be given for your participation in this research.

VII. Freedom to Withdraw

You are free to withdraw from this study at any time without penalty.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University, by the Department of Industrial and Systems Engineering.

IX. Subject's Responsibilities

I voluntarily agree to participate in this study. I agree to not discuss any aspect of this research with others until after the study has been completed.

X. Subject's Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project.

If I participate, I may withdraw at any time without penalty.

Signature Date

If I have any questions about this research I will contact:

Paige E. Smith (540) 231-4301 pasmith2@vt.edu
Principal Investigator

Dr. Brian M. Kleiner (540) 231-4926 bkleiner@vt.edu
Faculty Advisor

Mr. Tom Hurd (540) 231-5281
Chair, Institutional Review Board

Appendix A.6 Laboratory Setup

Lab setup.

1. Restart all computers
2. Set up videotaping equipment:
    - 2.1. subject taping
        - 2.1.1. setup high 8 camera
            - 2.1.1.1. plug in VCR
            - 2.1.1.2. plug in camera using the power pack
            - 2.1.1.3. plug video cable from camera to VCR-in
            - 2.1.1.4. plug VCR cable from VCR-out to monitor-in
            - 2.1.1.5. plug in microphone to power (use flexi-cam)
            - 2.1.1.6. connect microphone from source to VCR-in (use the teleconferencing microphone)
            - 2.1.1.7. plug audio from VCR-out to monitor-in
            - 2.1.1.8. turn on power for camera (left front), VCR, monitor
            - 2.1.1.9. turn on audio
            - 2.1.1.10. to zoom in and out use W_L button on top front
            - 2.1.1.11. insert tape into VCR
            - 2.1.1.12. push record when ready
        - 2.1.2. setup flexi-cam for tutor taping
            - 2.1.2.1. plug in VCR
            - 2.1.2.2. plug in camera using the power pack
            - 2.1.2.3. plug video cable from camera to VCR-in
            - 2.1.2.4. plug VCR cable from VCR-out to monitor-in
            - 2.1.2.5. plug in microphone to power
            - 2.1.2.6. connect microphone from source to VCR-in (use flexi-cam)
            - 2.1.2.7. plug audio from VCR-out to monitor-in
            - 2.1.2.8. turn on power for camera
            - 2.1.2.9. turn on power for audio
            - 2.1.2.10. check mirror to see if feedback cue visible
            - 2.1.2.11. insert tape into VCR
            - 2.1.2.12. push record when ready
    - 2.2. Monitor taping (both monitors)
        - 2.2.1. set computer screen 640x480 true color (24 bit) [originally 1024x768 true color, 24 bit)
        - 2.2.2. plug in adapter
        - 2.2.3. plug adapter into switch box
        - 2.2.4. plug monitor into switch box
        - 2.2.5. plug VCR into switch box
        - 2.2.6. plug VCR into monitor to verify working
        - 2.2.7. push record when ready
    - 2.3. Eudora™ – email (PID's Student1, Tutor)
        - 2.3.1. Start - EudoraLight™
        - 2.3.2. tools:
            - 2.3.2.1. getting started
                - 2.3.2.1.1. Pop Acct: PID@hci.ise.vt.edu
                - 2.3.2.1.2. Real Name: student# or tutor
                - 2.3.2.1.3. connection: ● winsock

2.3.2.2. Personal info:
2.3.2.2.1. Pop acct: PID@hci.ise.vt.edu
2.3.2.2.2. Real Name: student# or tutor
2.3.2.2.3. Return Address: PID@hci.ise.vt.edu
2.3.2.2.4. Dial up: blank
2.3.2.3. Host:
2.3.2.3.1. Pop: PID@hci.ise.vt.edu
2.3.2.3.2. SMTP: hci.ise.vt.edu
2.3.2.3.3. Ph: blank
2.3.2.3.4. finger: blank
2.3.2.4. checking mail:
2.3.2.4.1. POP: PID@hci.ise.vt.edu
2.3.2.4.2. ✓send on check
2.3.2.4.3. ● authentication: passwords
2.3.2.5. Sending:✓all options
2.3.2.6. font/display
2.3.2.6.1. screen courier new, 9
2.3.2.6.2. print courier new, 12
2.3.2.6.3. message width: 80
2.3.2.6.4. message height: 20
2.3.2.6.5. ✓zoom, show toolbar, show toolbar tips, show status bar, show category icons
2.3.2.7. getting attention: ✓user alert and open mailbox
2.3.2.8. dialup:
2.3.2.8.1. modem * data bits 8
2.3.2.8.2. baud 9600 stopbits 1
2.3.2.8.3. comport COM2 parity none
2.3.2.8.4. flow control hardware
2.3.2.8.5. service provider *
2.3.2.8.6. dial up time out after 60 sec
2.3.2.8.7. ✓CRLF and show trace
2.3.2.9. misc.
2.3.2.9.1. ✓require confirmation for deletes
2.3.2.9.2. ✓say OK to alerts after 2 min
2.3.2.9.3. ✓automatically open next message
2.3.2.10. advanced network
2.3.2.10.1. time out 60
2.3.2.10.2. buffer 4096
2.3.2.10.3. ✓cache network info
2.3.2.11. Set up mail boxes: Task 1 (cue/nocue) Task 2 (cue/nocue) Task 3 (cue/nocue) Task 4 (cue/nocue) Task 5 (cue/nocue) Task 6(cue/nocue) Task 7 (cue/nocue) Task 8 (cue/nocue)

2.3.3. open screen to full screen
2.3.4. open In mail to fit top half of screen
2.3.5. open Out mail to fit bottom half of screen
2.3.6. check mail once and enter password: PaigeSmith
2.3.7. make sure automatically checks mail every minute
2.3.8. if slow, send messages on highest priority

2.4. Chat: Microsoft® NetMeeting™
2.4.1. Start - Microsoft® NetMeeting™

2.4.2. Tools - Option...
2.4.2.1. First Name “Student” (Tut)
2.4.2.2. Last Name “1” (or)
2.4.2.3. After pressing enter: Answer no to logging onto server
2.4.3. tutor machine: call➔host meeting
2.4.4. call student computers: call: type in computer name (marjoram, rosemary, thyme). At student computer, press accept (it will tell the tutor if they hang up)
2.4.5. open chatroom by pressing the chat icon (6th from left side of screen and 3rd line of information from the top) (or under tools select chat)
2.4.5.1. Options
2.4.5.1.1. font: ms sans serif 8 regular
2.4.5.1.2. chat format
2.4.5.1.2.1. ✓ person’s name
2.4.5.1.2.2. ✓ date
2.4.5.1.2.3. bullet wrap text (bottom choice)
2.4.6. save file as: student number and condition (e.g., cueprob#.txt or nocueprob#.txt) save while student is filling out questionnaire

2.5. Video teleconferencing (CUSeeMe™)
2.5.1. Start - Enhanced CUSeeMe™
2.5.2. Conference - call - parsley
2.5.3. Tools - open local
2.5.4. Conference -
2.5.4.1. call (type in parsley)
2.5.4.2. chat
2.5.4.2.1. ms san serif, 8 (in config.)
2.5.5. Window - local video, audio (remote if not automatically opened)
2.5.6. Order (left to right across screen): top left, remote; bottom left, local, center audio, right chat.
2.5.7. Check flexi-cam centered on subject & audio working

2.6. Materials for students (collocated: all on table; virtual conditions: one at each station)
2.6.1. textbook (1)
2.6.2. pencils (1)
2.6.3. erasers (1)
2.6.4. rulers (1)
2.6.5. calculators (1)
2.6.6. scrap paper

Appendix A.7 Subjects' Raw Scores for Accuracy and Time

Table A.7.1 Raw scores for accuracy and time in phase 1

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	collocated	1	1	1.0	2.0
no cue	collocated	2	2	9.0	9.0
no cue	collocated	3	8	7.0	11.0
no cue	collocated	4	3	10.0	2.0
no cue	collocated	5	7	5.0	3.0
no cue	collocated	6	4	10.0	1.0
no cue	collocated	7	6	8.0	1.0
no cue	collocated	8	5	10.0	2.0
no cue	email	1	2	7.0	8.0
no cue	email	2	3	2.0	6.0
no cue	email	3	1	10.0	4.0
no cue	email	4	4	10.0	3.0
no cue	email	5	8	8.0	3.0
no cue	email	6	5	10.0	3.0
no cue	email	7	7	8.0	6.0
no cue	email	8	6	10.0	4.0
no cue	chatroom	1	3	10.0	5.0
no cue	chatroom	2	4	10.0	5.0
no cue	chatroom	3	2	10.0	5.0
no cue	chatroom	4	5	10.0	7.0
no cue	chatroom	5	1	10.0	4.0
no cue	chatroom	6	6	10.0	5.0
no cue	chatroom	7	8	6.0	1.0
no cue	chatroom	8	7	10.0	4.0
no cue	video teleconferencing	1	4	1.0	4.0
no cue	video teleconferencing	2	5	3.0	12.0
no cue	video teleconferencing	3	3	5.0	1.0
no cue	video teleconferencing	4	6	10.0	3.0
no cue	video teleconferencing	5	2	1.0	2.0
no cue	video teleconferencing	6	7	10.0	5.0
no cue	video teleconferencing	7	1	8.0	1.0
no cue	video teleconferencing	8	8	6.0	1.0
cue	collocated	1	5	8.0	3.0
cue	collocated	2	6	10.0	3.0
cue	collocated	3	4	3.0	1.0
cue	collocated	4	7	10.0	3.0
cue	collocated	5	3	10.0	3.0
cue	collocated	6	8	10.0	2.0
cue	collocated	7	2	10.0	1.0
cue	collocated	8	1	5.0	3.0

Table A.7.1 Raw scores for accuracy and time in phase 1 (continued)

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
cue	email	1	6	3.0	9.0
cue	email	2	7	10.0	9.0
cue	email	3	5	10.0	6.0
cue	email	4	8	5.0	4.0
cue	email	5	4	10.0	1.0
cue	email	6	1	10.0	13.0
cue	email	7	3	10.0	5.0
cue	email	8	2	10.0	3.0
cue	chatroom	1	7	10.0	3.0
cue	chatroom	2	8	10.0	2.0
cue	chatroom	3	6	10.0	11.0
cue	chatroom	4	1	10.0	4.0
cue	chatroom	5	5	10.0	3.0
cue	chatroom	6	2	2.0	6.0
cue	chatroom	7	4	8.0	3.0
cue	chatroom	8	3	6.0	2.0
cue	video teleconferencing	1	8	3.0	2.0
cue	video teleconferencing	2	1	4.0	7.0
cue	video teleconferencing	3	7	5.0	3.0
cue	video teleconferencing	4	2	10.0	1.0
cue	video teleconferencing	5	6	10.0	2.0
cue	video teleconferencing	6	3	10.0	2.0
cue	video teleconferencing	7	5	5.0	1.0
cue	video teleconferencing	8	4	10.0	2.0

Table A.7.2 Raw scores for accuracy and time in phase 2

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	collocated	1	1	6.0	5.0
no cue	collocated	2	2	10.0	10.0
no cue	collocated	3	8	8.0	8.0
no cue	collocated	4	3	7.0	5.0
no cue	collocated	5	7	8.0	10.0
no cue	collocated	6	4	1.0	8.0
no cue	collocated	7	6	8.0	2.0
no cue	collocated	8	5	7.0	6.0
no cue	email	1	2	7.0	11.0
no cue	email	2	3	4.0	4.0
no cue	email	3	1	9.0	25.0
no cue	email	4	4	7.0	5.0
no cue	email	5	8	8.0	32.0
no cue	email	6	5	10.0	33.0
no cue	email	7	7	8.0	4.0
no cue	email	8	6	7.0	22.0

Table A.7.2 Raw scores for accuracy and time in phase 2 (continued)

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	chatroom	1	3	8.0	7.0
no cue	chatroom	2	4	8.0	6.0
no cue	chatroom	3	2	4.0	5.0
no cue	chatroom	4	5	6.0	6.0
no cue	chatroom	5	1	8.0	28.0
no cue	chatroom	6	6	4.0	28.0
no cue	chatroom	7	8	10.0	3.0
no cue	chatroom	8	7	5.0	11.0
no cue	video teleconferencing	1	4	3.0	11.0
no cue	video teleconferencing	2	5	5.0	3.0
no cue	video teleconferencing	3	3	10.0	2.0
no cue	video teleconferencing	4	6	7.0	13.0
no cue	video teleconferencing	5	2	4.0	2.0
no cue	video teleconferencing	6	7	10.0	23.0
no cue	video teleconferencing	7	1	8.0	2.0
no cue	video teleconferencing	8	8	6.0	6.0
cue	collocated	1	5	5.0	4.0
cue	collocated	2	6	10.0	9.0
cue	collocated	3	4	9.0	5.0
cue	collocated	4	7	10.0	7.0
cue	collocated	5	3	10.0	15.0
cue	collocated	6	8	7.0	12.0
cue	collocated	7	2	10.0	1.0
cue	collocated	8	1	8.0	16.0
cue	email	1	6	5.0	15.0
cue	email	2	7	10.0	15.0
cue	email	3	5	8.0	4.0
cue	email	4	8	9.0	12.0
cue	email	5	4	7.0	3.0
cue	email	6	1	10.0	29.0
cue	email	7	3	6.0	9.0
cue	email	8	2	10.0	30.0
cue	chatroom	1	7	6.0	7.0
cue	chatroom	2	8	5.0	12.0
cue	chatroom	3	6	10.0	16.0
cue	chatroom	4	1	9.0	13.0
cue	chatroom	5	5	5.0	5.0
cue	chatroom	6	2	5.0	17.0
cue	chatroom	7	4	6.0	2.0
cue	chatroom	8	3	7.0	12.0
cue	video teleconferencing	1	8	4.0	6.0
cue	video teleconferencing	2	1	7.0	6.0
cue	video teleconferencing	3	7	9.0	3.0
cue	video teleconferencing	4	2	3.0	6.0
cue	video teleconferencing	5	6	8.0	23.0
cue	video teleconferencing	6	3	4.0	9.0
cue	video teleconferencing	7	5	10.0	3.0
cue	video teleconferencing	8	4	4.0	2.0

Table A.7.3 Raw scores for accuracy and time in phase 3

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	collocated	1	1	5.0	2.0
no cue	collocated	2	2	10.0	7.0
no cue	collocated	3	8	4.0	7.0
no cue	collocated	4	3	8.0	9.0
no cue	collocated	5	7	7.0	16.0
no cue	collocated	6	4	6.0	10.0
no cue	collocated	7	6	10.0	24.0
no cue	collocated	8	5	10.0	14.0
no cue	email	1	2	2.0	21.0
no cue	email	2	3	5.0	5.0
no cue	email	3	1	9.0	7.0
no cue	email	4	4	1.0	7.0
no cue	email	5	8	1.0*	*
no cue	email	6	5	10.0	5.0
no cue	email	7	7	10.0	26.0
no cue	email	8	6	9.0	21.0
no cue	chatroom	1	3	5.0	7.0
no cue	chatroom	2	4	10.0	20.0
no cue	chatroom	3	2	3.0	30.0
no cue	chatroom	4	5	8.0	5.0
no cue	chatroom	5	1	3.0	19.0
no cue	chatroom	6	6	6.0	9.0
no cue	chatroom	7	8	8.0	26.0
no cue	chatroom	8	7	10.0	28.0
no cue	video teleconferencing	1	4	5.0	4.0
no cue	video teleconferencing	2	5	5.0	7.0
no cue	video teleconferencing	3	3	6.0	5.0
no cue	video teleconferencing	4	6	3.0	9.0
no cue	video teleconferencing	5	2	1.0	31.0
no cue	video teleconferencing	6	7	10.0	10.0
no cue	video teleconferencing	7	1	10.0	44.0
no cue	video teleconferencing	8	8	3.0	32.0
cue	collocated	1	5	5.0	1.0
cue	collocated	2	6	10.0	7.0
cue	collocated	3	4	2.0	2.0
cue	collocated	4	7	10.0	16.0
cue	collocated	5	3	10.0	2.0
cue	collocated	6	8	6.0	3.0
cue	collocated	7	2	10.0	32.0
cue	collocated	8	1	8.0	17.0
cue	email	1	6	5.0	12.0
cue	email	2	7	10.0	4.0
cue	email	3	5	8.0	7.0
cue	email	4	8	5.0	8.0
cue	email	5	4	3.0	19.0
cue	email	6	1	10.0	3.0
cue	email	7	3	6.0	33.0
cue	email	8	2	2.0	16.0

*Incomplete data point

Table A.7.3 Raw scores for accuracy and time in phase 3 (continued)

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
cue	chatroom	1	7	6.0	5.0
cue	chatroom	2	8	5.0	18.0
cue	chatroom	3	6	8.0	12.0
cue	chatroom	4	1	7.0	6.0
cue	chatroom	5	5	7.0	13.0
cue	chatroom	6	2	6.0	2.0
cue	chatroom	7	4	10.0	30.0
cue	chatroom	8	3	3.0	21.0
cue	video teleconferencing	1	8	4.0	18.0
cue	video teleconferencing	2	1	5.0	3.0
cue	video teleconferencing	3	7	7.0	4.0
cue	video teleconferencing	4	2	4.0	26.0
cue	video teleconferencing	5	6	10.0	18.0
cue	video teleconferencing	6	3	6.0	1.0
cue	video teleconferencing	7	5	10.0	8.0
cue	video teleconferencing	8	4	5.0*	*

*Incomplete data point

Table A.7.4 Raw scores for accuracy and time in phase 4

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	collocated	1	1	8.0	12.0
no cue	collocated	2	2	10.0	5.0
no cue	collocated	3	8	10.0	12.0
no cue	collocated	4	3	9.0	13.0
no cue	collocated	5	7	8.0	10.0
no cue	collocated	6	4	10.0	6.0
no cue	collocated	7	6	8.0	7.0
no cue	collocated	8	5	8.0	4.0
no cue	email	1	2	10.0	13.0
no cue	email	2	3	8.0	30.0
no cue	email	3	1	7.0*	*
no cue	email	4	4	4.0	39.0
no cue	email	5	8	6.0*	*
no cue	email	6	5	10.0	16.0
no cue	email	7	7	8.0	10.0
no cue	email	8	6	8.0	8.0
no cue	chatroom	1	3	8.0	27.0
no cue	chatroom	2	4	10.0	10.0
no cue	chatroom	3	2	4.0	15.0
no cue	chatroom	4	5	10.0	13.0
no cue	chatroom	5	1	6.0	5.0
no cue	chatroom	6	6	10.0	15.0
no cue	chatroom	7	8	9.0	14.0
no cue	chatroom	8	7	8.0	13.0

*Incomplete data point

Table A.7.4 Raw scores for accuracy and time in phase 4 (continued)

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	video teleconferencing	1	4	5.0	16.0
no cue	video teleconferencing	2	5	8.0	13.0
no cue	video teleconferencing	3	3	9.0	19.0
no cue	video teleconferencing	4	6	8.0*	*
no cue	video teleconferencing	5	2	6.0	16.0
no cue	video teleconferencing	6	7	10.0	4.0
no cue	video teleconferencing	7	1	9.0	3.0
no cue	video teleconferencing	8	8	4.0*	*
cue	collocated	1	5	10.0	8.0
cue	collocated	2	6	10.0	5.0
cue	collocated	3	4	9.0	14.0
cue	collocated	4	7	10.0	4.0
cue	collocated	5	3	10.0	2.0
cue	collocated	6	8	10.0	15.0
cue	collocated	7	2	10.0	8.0
cue	collocated	8	1	8.0	16.0
cue	email	1	6	3.0*	*
cue	email	2	7	10.0	18.0
cue	email	3	5	8.0	38.0
cue	email	4	8	4.0*	*
cue	email	5	4	10.0	33.0
cue	email	6	1	10.0	12.0
cue	email	7	3	9.0	10.0
cue	email	8	2	10.0	8.0
cue	chatroom	1	7	6.0	23.0
cue	chatroom	2	8	8.0	10.0
cue	chatroom	3	6	10.0	17.0
cue	chatroom	4	1	5.0*	*
cue	chatroom	5	5	7.0	23.0
cue	chatroom	6	2	8.0	23.0
cue	chatroom	7	4	7.0	5.0
cue	chatroom	8	3	5.0*	*
cue	video teleconferencing	1	8	8.0	12.0
cue	video teleconferencing	2	1	10.0	15.0
cue	video teleconferencing	3	7	9.0	10.0
cue	video teleconferencing	4	2	7.0	19.0
cue	video teleconferencing	5	6	9.0	4.0
cue	video teleconferencing	6	3	10.0	21.0
cue	video teleconferencing	7	5	9.0	4.0
cue	video teleconferencing	8	4	9.0	26.0

*Incomplete data point

Table A.7.5 Raw overall scores for accuracy and time

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
no cue	collocated	1	1	20	21
no cue	collocated	2	2	39	31
no cue	collocated	3	8	29	38
no cue	collocated	4	3	34	29
no cue	collocated	5	7	28	39
no cue	collocated	6	4	27	25
no cue	collocated	7	6	34	34
no cue	collocated	8	5	35	26
no cue	email	1	2	26	53
no cue	email	2	3	19	45
no cue	email	3	1	35*	*
no cue	email	4	4	22	54
no cue	email	5	8	23*	*
no cue	email	6	5	40	57
no cue	email	7	7	34	46
no cue	email	8	6	34	55
no cue	chatroom	1	3	31	46
no cue	chatroom	2	4	38	41
no cue	chatroom	3	2	21	55
no cue	chatroom	4	5	34	31
no cue	chatroom	5	1	27	56
no cue	chatroom	6	6	30	57
no cue	chatroom	7	8	33	44
no cue	chatroom	8	7	33	56
no cue	video teleconferencing	1	4	14	35
no cue	video teleconferencing	2	5	21	35
no cue	video teleconferencing	3	3	30	27
no cue	video teleconferencing	4	6	28*	*
no cue	video teleconferencing	5	2	12	51
no cue	video teleconferencing	6	7	40	42
no cue	video teleconferencing	7	1	35	50
no cue	video teleconferencing	8	8	19*	*
cue	collocated	1	5	28	16
cue	collocated	2	6	40	24
cue	collocated	3	4	23	22
cue	collocated	4	7	40	30
cue	collocated	5	3	40	22
cue	collocated	6	8	33	32
cue	collocated	7	2	40	42
cue	collocated	8	1	29	52
cue	email	1	6	16*	*
cue	email	2	7	40	46
cue	email	3	5	34	55
cue	email	4	8	23*	*
cue	email	5	4	30	56
cue	email	6	1	40	57
cue	email	7	3	31	57
cue	email	8	2	32	57

*Incomplete data point

Table A.7.5 Raw overall scores for accuracy and time (continued)

Feedback Cue Level	Technology Level	Task	Subject	Accuracy	Time
cue	chatroom	1	7	28	38
cue	chatroom	2	8	28	42
cue	chatroom	3	6	38	56
cue	chatroom	4	1	31*	*
cue	chatroom	5	5	29	44
cue	chatroom	6	2	21	48
cue	chatroom	7	4	31	40
cue	chatroom	8	3	21*	*
cue	video teleconferencing	1	8	19	38
cue	video teleconferencing	2	1	26	31
cue	video teleconferencing	3	7	30	20
cue	video teleconferencing	4	2	24	52
cue	video teleconferencing	5	6	37	47
cue	video teleconferencing	6	3	30	33
cue	video teleconferencing	7	5	34	16
cue	video teleconferencing	8	4	28*	*

*Incomplete data point

Appendix A.8 Subjects' Supplemental Questionnaire Responses

The tables in this section contain raw data collected in the supplemental questionnaire. The following are the questions referred in these tables:

Phases 1 - 4

Question 1: Perceived Accuracy of Task
Question 2: Perceived Understanding of Task Outcome
Question 3: Perceived Conflict between Tutor and Subject
Question 4: Communication Method's Ease of Use
Question 5: Communication Method's Efficiency
Question 6: Communication Method's Effectiveness
Question 7: Satisfaction with Communication Method
Question 8: Tutor Completely Answering Questions
Question 9: Comfort Level with Tutor
Question 10: Overall Satisfaction with Tutoring Process

Overall

Question 1: Perceived Accuracy of Task
Question 2: Perceived Understanding of Task Outcome
Question 3: Perceived Conflict between Tutor and Subject
Question 4: Communication Method's Ease of Use
Question 5: Communication Method's Efficiency
Question 6: Communication Method's Effectiveness
Question 7: Satisfaction with Communication Method
Question 8: Satisfaction with Problem Solving Process
Question 9: Tutor Completely Answering Questions
Question 10: Comfort Level with Tutor
Question 11: Overall Satisfaction with Tutoring Process

Table A.8.1 Subjects' supplemental questionnaire responses in phase 1

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	collocated	1	1	2	3	4	3	3	3	3	5	4	4
no cue	collocated	2	2	3	4	4	5	5	4	4	4	4	5
no cue	collocated	3	8	4	4	5	5	4	4	4	5	4	4
no cue	collocated	4	3	5	5	5	5	5	5	5	5	5	5
no cue	collocated	5	7	4	4	5	5	4	5	5	5	5	5
no cue	collocated	6	4	5	5	5	5	5	5	5	5	5	5
no cue	collocated	7	6	4	4	4	4	4	4	4	4	4	4
no cue	collocated	8	5	3	4	4	4	3	4	4	3	4	4
no cue	email	1	2	4	4	5	5	4	3	5	3	4	4
no cue	email	2	3	5	5	5	1	1	1	1	5	5	4
no cue	email	3	1	3	3	3	4	4	3	3	4	4	4
no cue	email	4	4	5	5	5	3	3	3	2	5	5	3
no cue	email	5	8	3	4	3	3	3	3	3	3	3	3
no cue	email	6	5	4	4	4	4	3	3	3	3	3	3
no cue	email	7	7	5	5	5	4	4	4	5	5	4	5
no cue	email	8	6	4	4	4	3	2	3	2	4	3	3
no cue	chatroom	1	3	1	5	4	2	2	2	3	5	4	4
no cue	chatroom	2	4	2	3	4	3	3	3	3	3	4	3
no cue	chatroom	3	2	3	3	4	4	5	4	4	4	4	5
no cue	chatroom	4	5	3	3	2	2	2	2	2	3	3	3
no cue	chatroom	5	1	3	3	4	3	3	3	4	4	4	4
no cue	chatroom	6	6	4	4	4	4	4	4	4	4	4	4
no cue	chatroom	7	8	4	4	4	4	3	3	3	3	3	3
no cue	chatroom	8	7	4	4	4	4	5	5	5	5	5	5
no cue	video teleconferencing	1	4	5	3	3	4	4	4	2	4	4	4
no cue	video teleconferencing	2	5	2	3	2	2	2	2	2	4	4	2
no cue	video teleconferencing	3	3	5	5	3	1	2	1	2	5	4	4
no cue	video teleconferencing	4	6	4	4	4	4	4	4	3	4	4	4
no cue	video teleconferencing	5	2	3	3	4	4	5	5	5	4	4	4
no cue	video teleconferencing	6	7	3	3	4	5	4	4	4	4	5	5
no cue	video teleconferencing	7	1	3	3	3	3	3	3	4	4	4	4
no cue	video teleconferencing	8	8	3	4	4	4	3	3	3	4	4	4
cue	collocated	1	5	3	4	5	3	3	2	2	2	4	2
cue	collocated	2	6	4	4	4	3	3	3	3	3	3	3
cue	collocated	3	4	5	4	4	5	5	3	3	3	3	4
cue	collocated	4	7	4	4	4	5	5	5	5	4	5	5
cue	collocated	5	3	5	5	5	4	4	4	3	5	5	5
cue	collocated	6	8	3	4	4	4	4	4	4	4	4	4
cue	collocated	7	2	3	3	4	5	5	4	5	4	4	4
cue	collocated	8	1	3	3	4	3	3	4	4	4	4	4
cue	email	1	6	3	4	3	2	2	3	3	3	3	2
cue	email	2	7	3	4	4	4	4	4	4	4	5	4
cue	email	3	5	4	4	3	4	3	3	3	3	4	3
cue	email	4	8	3	4	3	2	2	2	3	3	3	2
cue	email	5	4	4	4	5	3	3	3	3	4	4	4
cue	email	6	1	3	4	4	3	3	3	4	4	4	4
cue	email	7	3	5	5	5	4	5	4	4	5	5	4
cue	email	8	2	3	3	4	4	4	4	4	4	5	4

Table A.8.1 Subjects' supplemental questionnaire responses in phase 1 (continued)

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
cue	chatroom	1	7	4	4	3	4	3	4	5	3	5	5
cue	chatroom	2	8	4	4	3	4	3	3	3	3	4	4
cue	chatroom	3	6	4	4	4	4	4	4	4	4	4	4
cue	chatroom	4	1	3	4	4	4	3	3	3	4	4	4
cue	chatroom	5	5	2	2	3	3	3	3	3	3	3	3
cue	chatroom	6	2	3	3	4	4	4	4	4	4	4	5
cue	chatroom	7	4	5	5	5	5	4	4	4	5	5	5
cue	chatroom	8	3	5	5	5	5	5	5	5	5	5	5
cue	video teleconferencing	1	8	4	4	4	4	3	4	3	4	4	4
cue	video teleconferencing	2	1	3	3	4	4	4	3	3	4	4	4
cue	video teleconferencing	3	7	4	4	4	5	5	5	5	4	5	5
cue	video teleconferencing	4	2	3	4	4	4	5	5	5	4	5	5
cue	video teleconferencing	5	6	4	4	4	4	4	4	4	4	4	4
cue	video teleconferencing	6	3	4	5	4	2	2	2	2	5	5	4
cue	video teleconferencing	7	5	4	4	4	4	4	4	4	3	4	4
cue	video teleconferencing	8	4	4	4	5	4	4	4	4	5	5	5

Table A.8.2 Subjects' supplemental questionnaire responses in phase 2

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	collocated	1	1	3	4	4	4	3	3	3	5	4	4
no cue	collocated	2	2	4	4	4	4	5	5	4	4	5	5
no cue	collocated	3	8	4	5	5	5	4	5	4	5	4	4
no cue	collocated	4	3	5	5	5	5	5	5	5	5	5	5
no cue	collocated	5	7	3	4	4	5	4	5	5	5	5	5
no cue	collocated	6	4	4	4	4	5	5	5	5	5	5	5
no cue	collocated	7	6	4	4	4	4	4	4	4	4	4	4
no cue	collocated	8	5	3	3	4	4	4	4	4	4	4	4
no cue	email	1	2	4	4	4	5	5	5	4	5	5	5
no cue	email	2	3	5	5	5	1	1	4	3	5	5	4
no cue	email	3	1	3	3	4	3	3	3	3	4	4	4
no cue	email	4	4	3	3	5	3	2	3	2	5	5	3
no cue	email	5	8	3	3	2	2	2	2	2	3	3	3
no cue	email	6	5	2	3	4	3	2	2	2	4	4	3
no cue	email	7	7	5	5	5	4	4	5	5	4	5	5
no cue	email	8	6	3	3	3	2	2	2	2	4	3	2
no cue	chatroom	1	3	5	5	5	2	2	3	3	5	5	4
no cue	chatroom	2	4	3	3	4	3	3	3	3	3	4	3
no cue	chatroom	3	2	2	3	4	4	5	5	5	4	4	5
no cue	chatroom	4	5	4	4	3	3	3	3	3	3	3	3
no cue	chatroom	5	1	3	4	3	2	3	3	3	4	4	4
no cue	chatroom	6	6	4	4	4	4	4	4	4	4	4	4
no cue	chatroom	7	8	3	4	4	4	3	3	3	3	4	3
no cue	chatroom	8	7	4	5	5	5	5	5	5	5	5	5

Table A.8.2 Subjects' supplemental questionnaire responses in phase 2 (continued)

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	video teleconferencing	1	4	5	4	3	4	4	4	4	5	4	4
no cue	video teleconferencing	2	5	2	3	3	2	2	2	3	4	4	3
no cue	video teleconferencing	3	3	5	5	4	1	4	3	3	5	5	4
no cue	video teleconferencing	4	6	4	4	4	4	4	4	3	4	3	4
no cue	video teleconferencing	5	2	3	3	4	4	5	5	5	3	4	4
no cue	video teleconferencing	6	7	4	4	4	5	4	4	4	4	4	5
no cue	video teleconferencing	7	1	3	4	4	3	3	3	4	4	4	4
no cue	video teleconferencing	8	8	3	4	3	4	3	4	4	4	4	4
cue	collocated	1	5	5	5	4	3	2	2	3	3	4	3
cue	collocated	2	6	4	4	4	4	4	4	4	4	3	4
cue	collocated	3	4	3	3	3	5	4	4	3	4	3	3
cue	collocated	4	7	4	4	4	5	5	5	5	4	5	5
cue	collocated	5	3	5	5	5	4	4	4	4	5	5	4
cue	collocated	6	8	4	4	4	4	4	4	4	4	4	4
cue	collocated	7	2	3	3	4	4	5	4	5	4	5	4
cue	collocated	8	1	3	3	4	3	3	3	4	4	4	4
cue	email	1	6	3	4	4	2	2	3	3	3	3	2
cue	email	2	7	4	4	4	4	4	4	5	4	5	5
cue	email	3	5	4	4	3	3	3	3	3	3	3	3
cue	email	4	8	3	4	2	2	2	2	2	4	2	4
cue	email	5	4	4	4	4	3	3	3	3	4	4	4
cue	email	6	1	3	4	4	4	4	4	4	4	4	4
cue	email	7	3	4	4	5	5	5	5	4	5	5	5
cue	email	8	2	3	3	4	4	4	4	4	4	4	4
cue	chatroom	1	7	4	4	4	5	3	4	4	3	4	5
cue	chatroom	2	8	4	4	5	5	5	5	4	5	4	5
cue	chatroom	3	6	4	4	4	4	4	4	4	4	4	4
cue	chatroom	4	1	3	4	4	3	4	3	4	4	4	4
cue	chatroom	5	5	4	4	3	4	3	3	3	3	3	3
cue	chatroom	6	2	3	3	4	4	4	4	4	4	4	4
cue	chatroom	7	4	5	5	5	5	4	4	4	5	5	5
cue	chatroom	8	3	5	5	5	5	5	5	5	5	5	5
cue	video teleconferencing	1	8	3	4	2	3	3	4	3	4	4	4
cue	video teleconferencing	2	1	3	4	4	4	4	3	3	5	4	4
cue	video teleconferencing	3	7	5	5	4	4	4	4	5	4	5	5
cue	video teleconferencing	4	2	4	4	4	5	5	5	5	4	4	5
cue	video teleconferencing	5	6	3	3	3	2	2	2	2	4	3	3
cue	video teleconferencing	6	3	5	5	4	3	2	1	1	5	5	5
cue	video teleconferencing	7	5	4	4	4	4	3	4	4	3	4	4
cue	video teleconferencing	8	4	4	3	5	4	4	4	4	5	5	5

Table A.8.3 Subjects' supplemental questionnaire responses in phase 3

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	collocated	1	1	3	4	4	3	3	3	4	5	4	4
no cue	collocated	2	2	3	3	4	4	4	4	4	4	4	4
no cue	collocated	3	8	4	5	5	4	4	4	4	5	4	4
no cue	collocated	4	3	5	5	5	5	5	5	5	5	5	5
no cue	collocated	5	7	3	4	5	5	5	5	5	5	5	5
no cue	collocated	6	4	3	3	3	4	5	4	5	4	5	5
no cue	collocated	7	6	4	4	4	4	4	4	4	4	4	4
no cue	collocated	8	5	3	3	4	4	4	4	4	4	4	4
no cue	email	1	2	4	3	2	4	2	4	3	2	4	3
no cue	email	2	3	5	5	5	1	1	2	2	5	5	4
no cue	email	3	1	3	3	4	3	3	3	3	4	4	3
no cue	email	4	4	5	5	4	3	2	2	1	5	5	2
no cue	email	5	8	2	4	2	2	2	2	2	4	3	2
no cue	email	6	5	3	3	3	3	3	3	3	3	3	3
no cue	email	7	7	5	5	4	5	4	5	5	4	5	5
no cue	email	8	6	4	4	5	4	3	4	2	2	3	3
no cue	chatroom	1	3	5	1	5	4	2	2	2	5	5	4
no cue	chatroom	2	4	4	3	4	4	3	4	4	5	4	4
no cue	chatroom	3	2	3	3	5	5	5	5	4	4	5	5
no cue	chatroom	4	5	3	4	3	3	3	3	2	3	3	3
no cue	chatroom	5	1	1	2	2	3	3	2	3	3	3	3
no cue	chatroom	6	6	4	4	4	4	4	4	4	4	4	4
no cue	chatroom	7	8	2	2	4	3	3	3	3	4	4	3
no cue	chatroom	8	7	4	4	4	5	5	5	5	5	5	5
no cue	video teleconferencing	1	4	5	2	4	4	4	5	4	5	4	4
no cue	video teleconferencing	2	5	2	2	2	2	2	2	2	3	4	2
no cue	video teleconferencing	3	3	5	5	5	3	4	3	3	5	4	4
no cue	video teleconferencing	4	6	4	4	4	4	4	4	3	4	4	3
no cue	video teleconferencing	5	2	3	3	4	4	5	5	5	4	4	4
no cue	video teleconferencing	6	7	4	4	4	4	5	5	5	5	5	5
no cue	video teleconferencing	7	1	4	4	4	4	3	4	4	4	4	4
no cue	video teleconferencing	8	8	3	4	4	4	4	4	4	4	4	4
cue	collocated	1	5	5	5	4	3	2	3	3	4	4	3
cue	collocated	2	6	4	4	4	4	4	4	4	4	4	4
cue	collocated	3	4	3	3	5	5	5	5	2	4	5	3
cue	collocated	4	7	4	4	4	4	5	5	5	4	5	5
cue	collocated	5	3	5	5	5	4	3	3	3	5	5	5
cue	collocated	6	8	4	4	4	4	4	4	4	4	4	4
cue	collocated	7	2	5	5	5	5	5	4	5	5	5	5
cue	collocated	8	1	3	3	4	3	3	3	3	4	4	4
cue	email	1	6	3	4	3	2	2	2	2	3	2	2
cue	email	2	7	4	4	5	4	4	5	5	4	5	5
cue	email	3	5	4	4	3	3	3	3	3	3	3	3
cue	email	4	8	3	4	2	2	2	2	2	4	3	2
cue	email	5	4	3	3	4	3	3	3	3	3	4	3
cue	email	6	1	3	4	4	4	4	4	4	4	4	4
cue	email	7	3	3	3	3	4	3	4	4	5	5	4
cue	email	8	2	3	3	4	4	4	4	5	4	4	4

Table A.8.3 Subjects' supplemental questionnaire responses in phase 3 (continued)

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
cue	chatroom	1	7	4	4	4	5	4	4	5	4	4	5
cue	chatroom	2	8	5	5	4	4	4	4	4	5	4	5
cue	chatroom	3	6	4	4	4	4	4	4	4	4	4	4
cue	chatroom	4	1	3	4	4	3	3	3	4	4	4	4
cue	chatroom	5	5	2	3	3	3	3	3	3	3	4	4
cue	chatroom	6	2	3	3	5	4	5	4	5	4	4	5
cue	chatroom	7	4	5	5	5	4	4	4	4	5	5	5
cue	chatroom	8	3	5	5	5	5	5	5	5	5	5	5
cue	video teleconferencing	1	8	4	5	3	4	4	4	4	4	4	4
cue	video teleconferencing	2	1	3	3	4	4	4	3	3	5	4	4
cue	video teleconferencing	3	7	4	4	4	5	5	4	5	4	5	5
cue	video teleconferencing	4	2	4	4	5	5	5	5	4	4	5	5
cue	video teleconferencing	5	6	3	3	2	2	2	2	2	4	3	2
cue	video teleconferencing	6	3	5	5	4	2	2	2	1	5	5	5
cue	video teleconferencing	7	5	4	4	4	4	3	3	4	3	4	4
cue	video teleconferencing	8	4	1	1	2	2	3	3	3	1	3	1

Table A.8.4 Subjects' supplemental questionnaire responses in phase 4

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	collocated	1	1	5	5	4	3	3	4	4	5	4	4
no cue	collocated	2	2	5	5	5	4	4	5	4	5	5	5
no cue	collocated	3	8	5	5	5	5	5	5	5	5	5	5
no cue	collocated	4	3	5	5	5	5	5	5	5	5	5	5
no cue	collocated	5	7	4	5	4	5	4	5	5	5	5	5
no cue	collocated	6	4	5	5	4	5	5	5	5	5	5	5
no cue	collocated	7	6	4	4	4	4	4	4	4	4	4	4
no cue	collocated	8	5	5	5	5	5	5	5	5	5	5	5
no cue	email	1	2	4	5	3	2	2	4	2	4	4	4
no cue	email	2	3	3	5	4	1	1	1	2	5	4	4
no cue	email	3	1	2	3	3	3	3	3	3	4	4	4
no cue	email	4	4	1	1	1	1	1	1	1	1	3	1
no cue	email	5	8	3	4	2	2	2	2	2	4	3	2
no cue	email	6	5	4	4	4	3	3	3	3	5	5	4
no cue	email	7	7	5	5	5	5	4	4	4	4	5	5
no cue	email	8	6	4	4	4	4	2	3	3	3	3	2
no cue	chatroom	1	3	1	5	4	2	2	2	1	5	5	3
no cue	chatroom	2	4	5	5	4	4	4	4	4	5	5	4
no cue	chatroom	3	2	5	4	5	5	5	5	5	4	5	5
no cue	chatroom	4	5	5	5	3	3	3	3	4	4	3	3
no cue	chatroom	5	1	4	5	3	3	3	3	3	3.5	3	4
no cue	chatroom	6	6	4	4	4	4	4	4	4	4	4	4
no cue	chatroom	7	8	5	5	4	4	3	4	3	4	4	4
no cue	chatroom	8	7	5	5	5	5	5	5	5	5	5	5

Table A.8.4 Subjects' supplemental questionnaire responses in phase 4 (continued)

				Question									
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10
no cue	video teleconferencing	1	4	5	5	3	5	5	5	4	5	5	5
no cue	video teleconferencing	2	5	5	5	4	2	2	2	2	4	4	4
no cue	video teleconferencing	3	3	4	5	1	1	2	1	1	5	4	1
no cue	video teleconferencing	4	6	3	3	2	2	2	3	3	4	3	3
no cue	video teleconferencing	5	2	5	5	5	4	4	4	4	4	4	4
no cue	video teleconferencing	6	7	5	5	4	4	5	5	5	5	5	5
no cue	video teleconferencing	7	1	4	5	4	3	3	4	4	4	4	4
no cue	video teleconferencing	8	8	3	4	4	4	4	4	4	4	4	4
cue	collocated	1	5	5	5	5	5	4	4	5	5	5	5
cue	collocated	2	6	5	4	5	4	5	5	4	5	4	4
cue	collocated	3	4	5	4	4	4	4	4	3	4	4	4
cue	collocated	4	7	5	5	5	5	4	5	5	4	5	5
cue	collocated	5	3	5	5	5	3	3	3	3	5	5	5
cue	collocated	6	8	5	5	4	4	4	4	4	4	4	5
cue	collocated	7	2	5	5	5	4	5	4	5	4	5	5
cue	collocated	8	1	5	4	4	4	3	4	4	4	4	4
cue	email	1	6	2	3	3	2	2	2	2	4	2	2
cue	email	2	7	4	4	4	4	5	5	5	4	5	5
cue	email	3	5	5	5	4	3	3	3	3	5	4	3
cue	email	4	8	5	5	2	1	1	1	1	3	3	2
cue	email	5	4	3	3	3	2	2	2	2	4	4	3
cue	email	6	1	4	4	4	4	3	4	4	4	4	4
cue	email	7	3	4	3	5	4	4	4	4	5	4	5
cue	email	8	2	5	5	4	4	4	5	5	4	5	5
cue	chatroom	1	7	5	5	5	4	4	4	5	4	4	4
cue	chatroom	2	8	5	5	5	5	5	5	5	5	5	5
cue	chatroom	3	6	4	4	4	4	3	4	4	4	4	4
cue	chatroom	4	1	1	4	2	2	1	1	2	1	3	3
cue	chatroom	5	5	5	5	4	4	3	3	3	4	4	4
cue	chatroom	6	2	5	5	5	5	5	5	5	5	5	5
cue	chatroom	7	4	5	5	5	5	4	4	4	5	5	5
cue	chatroom	8	3	2	5	5	4	3	4	4	5	5	5
cue	video teleconferencing	1	8	5	5	4	4	3	4	4	4	4	5
cue	video teleconferencing	2	1	5	4	4	4	3	3	3	5	4	4
cue	video teleconferencing	3	7	5	5	5	5	5	5	5	4	4	5
cue	video teleconferencing	4	2	5	5	4	4	4	5	5	4	5	5
cue	video teleconferencing	5	6	4	4	4	3	3	3	3	4	4	3
cue	video teleconferencing	6	3	5	5	4	2	1	1	1	5	5	4
cue	video teleconferencing	7	5	5	5	5	4	3	4	3	3	4	4
cue	video teleconferencing	8	4	3	3	3	3	4	3	3	4	4	3

Table A.8.5 Subjects' supplemental questionnaire responses for the overall tutoring process

				Question										
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10	11
no cue	collocated	1	1	5	4	4	3	3	4	4	4	5	4	4
no cue	collocated	2	2	5	5	5	4	4	4	5	5	5	5	4
no cue	collocated	3	8	5	5	5	5	5	5	5	5	5	5	5
no cue	collocated	4	3	5	5	5	5	5	5	5	5	5	5	5
no cue	collocated	5	7	5	5	5	5	4	5	4	5	4	4	5
no cue	collocated	6	4	5	5	5	5	5	5	5	3	5	5	5
no cue	collocated	7	6	5	4	5	5	5	5	4	4	5	4	5
no cue	collocated	8	5	5	5	5	5	5	5	4	4	5	4	4
no cue	email	1	2	3	4	2	4	2	4	2	5	4	4	4
no cue	email	2	3	3	5	5	1	1	3	1	5	5	5	5
no cue	email	3	1	2	4	3	3	3	3	3	4	4	4	4
no cue	email	4	4	1	3	1	1	1	1	1	1	3	3	1
no cue	email	5	8	2	4	2	2	2	2	2	4	4	3	2
no cue	email	6	5	4	4	4	3	2	3	3	4	5	5	3
no cue	email	7	7	5	5	5	5	4	4	4	5	4	5	5
no cue	email	8	6	4	4	4	3	3	3	2	4	4	4	3
no cue	chatroom	1	3	4	5	4	2	1	2	2	4	4	4	4
no cue	chatroom	2	4	5	5	4	4	4	4	4	3	5	5	4
no cue	chatroom	3	2	5	4	5	5	5	5	5	5	5	5	5
no cue	chatroom	4	5	5	5	4	3	3	3	3	3	4	4	4
no cue	chatroom	5	1	1	5	3	3	3	3	3	3	4	3	3
no cue	chatroom	6	6	4	4	4	4	4	4	4	4	4	5	5
no cue	chatroom	7	8	4	5	4	4	3	4	4	5	4	4	4
no cue	chatroom	8	7	4	5	5	5	5	5	5	5	4	5	5
no cue	video teleconferencing	1	4	5	5	3	5	5	5	5	3	5	5	5
no cue	video teleconferencing	2	5	5	4	3	2	2	2	2	2	4	4	3
no cue	video teleconferencing	3	3	5	5	1	2	1	1	1	3	5	5	1
no cue	video teleconferencing	4	6	3	3	3	3	3	3	3	3	4	3	3
no cue	video teleconferencing	5	2	5	5	4	4	4	4	4	4	4	5	5
no cue	video teleconferencing	6	7	5	5	5	4	5	5	5	5	5	5	5
no cue	video teleconferencing	7	1	4	5	4	3	3	3	4	4	4	4	4
no cue	video teleconferencing	8	8	2	4	4	4	4	4	4	4	4	4	4
cue	collocated	1	5	4	5	5	4	4	4	4	3	4	5	3
cue	collocated	2	6	5	4	4	5	4	4	5	4	5	4	4
cue	collocated	3	4	4	4	5	4	4	4	4	3	5	5	4
cue	collocated	4	7	5	5	5	5	4	5	5	5	4	5	5
cue	collocated	5	3	5	5	5	3	3	3	3	3	5	5	5
cue	collocated	6	8	5	5	4	4	4	4	4	5	4	4	5
cue	collocated	7	2	5	5	4	4	5	5	5	4	5	5	5
cue	collocated	8	1	5	4	4	4	3	3	4	4	4	4	4

Table A.8.5 Subjects' supplemental questionnaire responses for the overall tutoring process (continued)

				Question										
Feedback Cue	Technology	Task	Subject	1	2	3	4	5	6	7	8	9	10	11
cue	email	1	6	2	3	3	2	2	2	2	2	4	2	2
cue	email	2	7	5	5	4	4	4	4	5	5	5	4	5
cue	email	3	5	5	5	4	3	2	3	3	4	4	4	4
cue	email	4	8	5	5	1	1	1	1	1	4	3	3	1
cue	email	5	4	3	4	4	2	2	2	2	3	4	4	3
cue	email	6	1	4	4	4	4	3	4	4	4	4	4	4
cue	email	7	3	3	4	5	5	4	4	4	3	5	5	5
cue	email	8	2	5	5	4	4	5	5	4	5	5	5	5
cue	chatroom	1	7	5	5	5	5	5	5	5	5	4	4	4
cue	chatroom	2	8	5	5	5	4	4	4	4	5	5	4	5
cue	chatroom	3	6	4	4	4	4	3	4	4	4	4	4	4
cue	chatroom	4	1	1	4	3	2	2	2	3	2	3	3	3
cue	chatroom	5	5	5	5	3	3	2	3	3	4	4	4	4
cue	chatroom	6	2	5	5	5	5	5	5	5	5	5	5	5
cue	chatroom	7	4	5	5	5	5	4	4	4	5	5	5	5
cue	chatroom	8	3	5	5	5	5	4	4	4	5	5	5	5
cue	video teleconferencing	1	8	5	5	4	4	3	4	4	5	4	4	5
cue	video teleconferencing	2	1	5	4	4	4	4	3.5	4	4	5	4	4
cue	video teleconferencing	3	7	5	5	5	5	5	4	4	4	4	4	4
cue	video teleconferencing	4	2	5	5	4	4	4	5	5	5	5	5	5
cue	video teleconferencing	5	6	4	3	3	2	2	2	2	3	4	3	3
cue	video teleconferencing	6	3	5	5	5	1	2	2	2	5	5	5	5
cue	video teleconferencing	7	5	5	5	5	4	3	4	4	4	3	4	4
cue	video teleconferencing	8	4	3	4	3	3	3	3	3	3	4	4	3

Appendix A.9 Tutor's Responses to Supplemental Questions

Question 1: Student's understanding of the problem

Question 2: Communication method's ease of use

Question 3: Communication method's efficiency

Question 4: Communication method's effectiveness

Question 5: Satisfaction with communication method

Question 6: Completely answered subject's questions

Question 7: Overall satisfaction

Table A.9 Tutor's response to supplemental questions

Feedback Cue Level	Technology Level	Subject	Task	Q1	Q2	Q3	Q4	Q5	Q6	Q7
No Cue	Collocated	1	1	4	5	5	5	5	5	5
No Cue	Email	2	1	2	3	2	3	3	4	3
No Cue	Chatroom	3	1	4	5	5	5	5	4	5
No Cue	Video Teleconferencing	4	1	4	4	4	3	3	4	4
Cue	Collocated	5	1	5	5	5	5	5	5	5
Cue	Email	6	1	2	3	3	3	3	2	2
Cue	Chatroom	7	1	5	5	5	5	5	4	5
Cue	Video Teleconferencing	8	1	5	3	2	2	3	4	4
No Cue	Collocated	2	2	4	4	5	5	5	5	5
No Cue	Email	3	2	4	4	3	4	4	4	4
No Cue	Chatroom	4	2	5	5	4	4	5	5	5
No Cue	Video Teleconferencing	5	2	4	5	4	4	5	5	5
Cue	Collocated	6	2	4	4	5	5	5	4	5
Cue	Email	7	2	5	2	2	3	2	5	3
Cue	Chatroom	8	2	4	4	5	4	4	4	4
Cue	Video Teleconferencing	1	2	5	4	5	4	4	4	5
No Cue	Collocated	8	3	4	4	5	5	4	5	5
No Cue	Email	1	3	4	2	2	2	2	4	3
No Cue	Chatroom	2	3	2	5	4	4	4	2	3
No Cue	Video Teleconferencing	3	3	5	4	4	3	4	4	4
Cue	Collocated	4	3	4	5	5	5	5	5	4
Cue	Email	5	3	5	4	3	3	3	5	5
Cue	Chatroom	6	3	5	5	5	5	5	5	5
Cue	Video Teleconferencing	7	3	5	5	5	5	5	5	5
No Cue	Collocated	3	4	5	5	5	5	5	5	5
No Cue	Email	4	4	2	2	2	2	2	3	2
No Cue	Chatroom	5	4	5	5	5	5	5	5	5
No Cue	Video Teleconferencing	6	4	3	4	4	3	4	3	4
Cue	Collocated	7	4	5	5	5	5	5	5	5
Cue	Email	8	4	2	2	2	2	2	2	2
Cue	Chatroom	1	4	3	5	5	4	4	2	4
Cue	Video Teleconferencing	2	4	4	4	4	4	4	5	4

Table A.9 Tutors Responses to Supplemental Questionnaires (continued)

Feedback Cue Level	Technology Level	Subject	Task	Q1	Q2	Q3	Q4	Q5	Q6	Q7
No Cue	Collocated	7	5	5	5	5	5	5	5	5
No Cue	Email	8	5	2	1	2	2	1	3	2
No Cue	Chatroom	1	5	4	4	3	3	4	4	4
No Cue	Video Teleconferencing	2	5	3	4	3	3	2	4	3
Cue	Collocated	3	5	5	5	5	5	5	5	5
Cue	Email	4	5	3	2	1	1	1	5	2
Cue	Chatroom	5	5	5	5	5	4	5	5	5
Cue	Video Teleconferencing	6	5	4	4	4	4	4	5	4
No Cue	Collocated	4	6	4	5	5	5	5	5	5
No Cue	Email	5	6	4	2	2	2	3	4	3
No Cue	Chatroom	6	6	4	5	3	4	4	5	4
No Cue	Video Teleconferencing	7	6	5	5	5	5	5	5	5
Cue	Collocated	8	6	5	4	5	5	5	5	5
Cue	Email	1	6	4	2	2	2	2	5	3
Cue	Chatroom	2	6	4	4	3	4	4	5	4
Cue	Video Teleconferencing	3	6	5	5	4	4	5	5	5
No Cue	Collocated	6	7	4	5	5	5	5	5	5
No Cue	Email	7	7	5	3	2	3	3	5	3
No Cue	Chatroom	8	7	4	5	5	5	5	5	5
No Cue	Video Teleconferencing	1	7	5	4	4	5	4	5	5
Cue	Collocated	2	7	4	5	5	5	5	5	4
Cue	Email	3	7	4	2	2	2	1	2	2
Cue	Chatroom	4	7	5	5	5	5	5	5	5
Cue	Video Teleconferencing	5	7	5	5	5	5	5	5	5
No Cue	Collocated	5	8	5	5	5	5	5	5	5
No Cue	Email	6	8	3	1	1	2	2	3	2
No Cue	Chatroom	7	8	5	5	3	5	5	5	5
No Cue	Video Teleconferencing	8	8	4	4	3	3	4	4	4
Cue	Collocated	1	8	4	5	5	4	4	4	4
Cue	Email	2	8	3	2	1	1	1	3	2
Cue	Chatroom	3	8	2	4	3	3	3	2	2
Cue	Video Teleconferencing	4	8	2	4	3	4	4	3	4

Appendix A.10 MANOVA on Accuracy and Supplemental Accuracy Responses

Table A.10.1 MANOVA on accuracy and subjects' perceived accuracy and understanding

Criterion	Test Statistic	F	df		P
Feedback Cue					
Wilk's	0.284	4.207	3	5	0.078
Lawley-Hotelling	2.524	4.207	3	5	0.078
Pillai's	0.716	4.207	3	5	0.078
Technology					
Wilk's	0.543	1.471	9	46	0.187
Lawley-Hotelling	0.713	1.399	9	53	0.212
Pillai's	0.529	1.499	9	63	0.168
Phase					
Wilk's	0.289	3.432	9	46	0.003*
Lawley-Hotelling	1.950	3.827	9	53	0.001*
Pillai's	0.863	2.825	9	63	0.007*
Feedback Cue x Technology					
Wilk's	0.704	0.798	9	46	0.620
Lawley-Hotelling	0.381	0.747	9	53	0.664
Pillai's	0.324	0.847	9	63	0.577
Feedback Cues x Phase					
Wilk's	0.649	1.001	9	46	0.453
Lawley-Hotelling	0.532	1.044	9	53	0.419
Pillai's	0.356	0.943	9	63	0.495
Technology x Phase					
Wilk's	0.485	1.863	27	178	0.009*
Lawley-Hotelling	0.844	1.864	27	179	0.009*
Pillai's	0.628	1.854	27	189	0.009*
Feedback x Technology x Phase					
Wilk's	0.602	1.255	27	178	0.192
Lawley-Hotelling	0.566	1.250	27	179	0.196
Pillai's	0.457	1.258	27	189	0.189

*$p < 0.05$

Table A.10.2 MANOVA on overall accuracy, perceived accuracy and understanding, and tutor's perceived understanding

Criterion	Test Statistic	F	df		P
Feedback Cue					
Wilk's	0.422	1.368	4	4	0.384
Lawley-Hotelling	1.368	1.368	4	4	0.384
Pillai's	0.578	1.368	4	4	0.384
Technology					
Wilk's	0.289	2.391	12	47	0.017*
Lawley-Hotelling	1.679	2.332	12	50	0.018*
Pillai's	0.961	2.357	12	60	0.015*
Feedback Cue x Technology					
Wilk's	0.674	0.642	12	47	0.796
Lawley-Hotelling	0.446	0.619	12	50	0.816
Pillai's	0.352	0.664	12	60	0.778

*p < 0.05

Table A.10.3 MANOVA on accuracy (excluding incomplete data) and subjects' perceived accuracy and understanding

Criterion	Test Statistic	F	df		P
Feedback Cue					
Wilk's	0.294	4.005	3	5	0.085
Lawley-Hotelling	2.403	4.005	3	5	0.085
Pillai's	0.706	4.005	3	5	0.085
Technology					
Wilk's	0.564	1.367	9	46	0.231
Lawley-Hotelling	0.672	1.320	9	53	0.249
Pillai's	0.430	1.377	9	63	0.218
Phase					
Wilk's	0.215	4.533	9	46	<0.001*
Lawley-Hotelling	2.778	5.452	9	53	<0.001*
Pillai's	0.981	3.401	9	63	0.002*
Feedback Cue x Technology					
Wilk's	0.600	1.202	9	46	0.317
Lawley-Hotelling	0.588	1.155	9	53	0.343
Pillai's	0.447	1.225	9	63	0.296
Feedback Cues x Phase					
Wilk's	0.532	1.528	9	46	0.167
Lawley-Hotelling	0.854	1.676	9	53	0.118
Pillai's	0.483	1.343	9	63	0.233
Technology x Phase					
Wilk's	0.505	1.746	27	178	0.018*
Lawley-Hotelling	0.815	1.803	27	179	0.013*
Pillai's	0.582	1.685	27	189	0.024*
Feedback x Technology x Phase					
Wilk's	0.626	0.965	27	149	0.520
Lawley-Hotelling	0.518	0.953	27	149	0.536
Pillai's	0.427	0.976	27	159	0.505

*p < 0.05

Table A.10.4 MANOVA on overall accuracy (excluding incomplete data), subject's perceived accuracy and understanding, and tutor's perceived understanding

Criterion	Test Statistic	F	df		P
Feedback Cue					
Wilk's	0.250	2.998	4	4	0.156
Lawley-Hotelling	2.998	2.998	4	4	0.156
Pillai's	0.750	2.998	4	4	0.156
Technology					
Wilk's	0.293	2.361	12	47	0.018*
Lawley-Hotelling	1.810	2.514	12	50	0.011*
Pillai's	0.899	2.140	12	60	0.027*
Feedback Cue x Technology					
Wilk's	0.178	1.848	12	24	0.098
Lawley-Hotelling	3.190	2.038	12	23	0.069
Pillai's	1.091	1.571	12	33	0.149

*$p < 0.05$

Appendix A.11 Overall Accuracy ANOVA Table

Table A.11 ANOVA summary table for accuracy of overall tasks

Source	df	SS	MS	F	p-value
Between					
S	7	501.984	71.712		
Within					
C	1	37.516	37.516	5.430	0.053
CxS	7	48.359	6.908		
T	3	266.047	88.682	1.398	0.271
TxS	21	1332.578	63.456		
CxT	3	96.172	32.057	0.767	0.525
CxTxS	21	877.453	41.783		
Total	63	3160.109			

Appendix A.12 Analysis of Accuracy Excluding Incomplete Trial Data

Table A.12.1 Accuracy ANOVA summary table for all phases excluding incomplete trial data

Source	df	SS	MS	F	p-value
Between					
S	7	85.550	12.221		
Within					
P	3	86.017	28.672	9.022	0.000*
PxS	21	66.731	3.178		
C	1	6.855	6.855	2.588	0.152
CxS	7	18.547	2.650		
T	3	47.727	15.909	1.156	0.350
TxS	21	289.068	13.765		
PxC	3	0.265	0.0883	0.054	0.983
PxCxS	21	34.047	1.621		
PxT	9	59.211	6.579	1.559	0.148
PxTxS	62	261.586	4.219		
CxT	3	19.138	6.379	0.629	0.604
CxTxS	21	213.119	10.149		
PxCxT	9	23.104	2.567	0.468	0.890
PxCxTxS	54	296.510	5.491		
Total	245	1599.885			

*p < 0.01

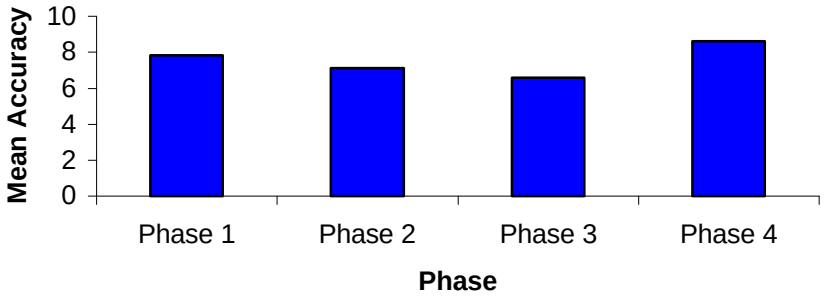


Figure A.12 Comparison of the mean accuracy for each phase excluding incomplete trial data

Table A.12.2 Multiple comparisons of mean accuracy between phase levels

			Phase 2	Phase 1	Phase 4
		mean	7.141	7.844	8.607
	mean				
Phase 3	6.613		0.528	1.231*	1.994*
Phase 2	7.141			0.703	1.466*
Phase 1	7.844				0.763

*p < 0.05

Table A.12.3 ANOVA summary table for overall accuracy (excluding incomplete data)

Source	df	SS	MS	F	p-value
Between					
S	7	464.936	66.419		
Within					
C	1	45.369	45.369	2.811	0.138
CxS	7	112.978	16.140		
T	3	321.092	107.031	1.927	0.158
TxS	20	1111.036	55.552		
CxT	3	91.949	30.650	0.901	0.467
CxTxS	13	442.426	34.033		
Total	54	2589.786			

Appendix A.13 Three-way interaction in the Perceived Accuracy Analysis

Table A.13 Multiple comparisons of the mean perceived accuracy for the three-way interaction

				phase 3 chat no cue	phase 3 email cue	phase 4 email no cue	phase 1 email cue	phase 1 vtc no cue	phase 2 chat no cue	phase 2 email cue	phase 2 email no cue
				3.250	3.250	3.250	3.500	3.500	3.500	3.500	3.500
phase 1	chat	no cue	3.000	0.250	0.250	0.250	0.500	0.500	0.500	0.500	0.500
phase 3	chat	no cue	3.250		0.000	0.000	0.250	0.250	0.250	0.250	0.250
phase 3	email	cue	3.250			0.000	0.250	0.250	0.250	0.250	0.250
phase 4	email	no cue	3.250				0.250	0.250	0.250	0.250	0.250
phase 1	email	cue	3.500					0.000	0.000	0.000	0.000
phase 1	vtc	no cue	3.500						0.000	0.000	0.000
phase 2	chat	no cue	3.500							0.000	0.000
phase 2	email	cue	3.500								0.000

Table A.13 Multiple comparisons of the mean perceived accuracy for the three-way interaction (continued)

				phase 3 collocated no cue	phase 3 vtc cue	phase 2 vtc no cue	phase 1 chat cue	phase 1 collocated cue	phase 1 collocated no cue	phase 1 vtc cue	phase 2 collocated no cue
				3.500	3.500	3.625	3.750	3.750	3.750	3.750	3.750
phase 1	chat	no cue	3.000	0.500	0.500	0.625	0.750	0.750	0.750	0.750	0.750
phase 3	chat	no cue	3.250	0.250	0.250	0.375	0.500	0.500	0.500	0.500	0.500
phase 3	email	cue	3.250	0.250	0.250	0.375	0.500	0.500	0.500	0.500	0.500
phase 4	email	no cue	3.250	0.250	0.250	0.375	0.500	0.500	0.500	0.500	0.500
phase 1	email	cue	3.500	0.000	0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 1	vtc	no cue	3.500	0.000	0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 2	chat	no cue	3.500	0.000	0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 2	email	cue	3.500	0.000	0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 2	email	no cue	3.500	0.000	0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 3	collocated	no cue	3.500		0.000	0.125	0.250	0.250	0.250	0.250	0.250
phase 3	vtc	cue	3.500			0.125	0.250	0.250	0.250	0.250	0.250
phase 2	vtc	no cue	3.625				0.125	0.125	0.125	0.125	0.125
phase 1	chat	cue	3.750					0.000	0.000	0.000	0.000
phase 1	collocated	cue	3.750						0.000	0.000	0.000
phase 1	collocated	no cue	3.750							0.000	0.000
phase 1	vtc	cue	3.750								0.000

Table A.13 Multiple comparisons of the mean perceived accuracy for the three-way interaction (continued)

				phase 3 vtc no cue	phase 2 collocated cue	phase 2 vtc cue	phase 3 chat cue	phase 3 email no cue	phase 2 chat cue	phase 4 chat cue	phase 4 email cue
				3.750	3.875	3.875	3.875	3.875	4.000	4.000	4.000
phase 1	chat	no cue	3.000	0.750	0.875	0.875	0.875	0.875	1.000*	1.000*	1.000*
phase 3	chat	no cue	3.250	0.500	0.625	0.625	0.625	0.625	0.750	0.750	0.750
phase 3	email	cue	3.250	0.500	0.625	0.625	0.625	0.625	0.750	0.750	0.750
phase 4	email	no cue	3.250	0.500	0.625	0.625	0.625	0.625	0.750	0.750	0.750
phase 1	email	cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 1	vtc	no cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 2	chat	no cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 2	email	cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 2	email	no cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 3	collocated	no cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 3	vtc	cue	3.500	0.250	0.375	0.375	0.375	0.375	0.500	0.500	0.500
phase 2	vtc	no cue	3.625	0.125	0.250	0.250	0.250	0.250	0.375	0.375	0.375
phase 1	chat	cue	3.750	0.000	0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 1	collocated	cue	3.750	0.000	0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 1	collocated	no cue	3.750	0.000	0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 1	vtc	cue	3.750	0.000	0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 2	collocated	no cue	3.750	0.000	0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 3	vtc	no cue	3.750		0.125	0.125	0.125	0.125	0.250	0.250	0.250
phase 2	collocated	cue	3.875			0.000	0.000	0.000	0.125	0.125	0.125
phase 2	vtc	cue	3.875				0.000	0.000	0.125	0.125	0.125
phase 3	chat	cue	3.875					0.000	0.125	0.125	0.125
phase 3	email	no cue	3.875						0.125	0.125	0.125
phase 2	chat	cue	4.000							0.000	0.000
phase 4	chat	cue	4.000								0.000

*$p < 0.05$

Table A.13 Multiple comparisons of the mean perceived accuracy for the three-way interaction (continued)

				phase 1 email no cue	phase 3 collocated cue	phase 4 chat no cue	phase 4 vtc no cue	phase 4 vtc cue	phase 4 collocated no cue	phase 4 collocated cue
				4.125	4.125	4.250	4.250	4.625	4.750	5.000
phase 1	chat	no cue	3.000	1.125*	1.125*	1.125*	1.125*	1.625*	1.750*	2.000*
phase 3	chat	no cue	3.250	0.875	0.875	1.000*	1.000*	1.375*	1.500*	1.750*
phase 3	email	cue	3.250	0.875	0.875	1.000*	1.000*	1.375*	1.500*	1.750*
phase 4	email	no cue	3.250	0.875	0.875	1.000*	1.000*	1.375*	1.500*	1.750*
phase 1	email	cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 1	vtc	no cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 2	chat	no cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 2	email	cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 2	email	no cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 3	collocated	no cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 3	vtc	cue	3.500	0.625	0.625	0.750	0.750	1.125*	1.250*	1.500*
phase 2	vtc	no cue	3.625	0.500	0.500	0.625	0.625	1.000*	1.125*	1.375*
phase 1	chat	cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 1	collocated	cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 1	collocated	no cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 1	vtc	cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 2	collocated	no cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 3	vtc	no cue	3.750	0.375	0.375	0.500	0.500	0.875	1.000*	1.250*
phase 2	collocated	cue	3.875	0.250	0.250	0.375	0.375	0.750	0.875	1.125*
phase 2	vtc	cue	3.875	0.250	0.250	0.375	0.375	0.750	0.875	1.125*
phase 3	chat	cue	3.875	0.250	0.250	0.375	0.375	0.750	0.875	1.125*
phase 3	email	no cue	3.875	0.250	0.250	0.375	0.375	0.750	0.875	1.125*
phase 2	chat	cue	4.000	0.125	0.125	0.250	0.250	0.625	0.750	1.000*
phase 4	chat	cue	4.000	0.125	0.125	0.250	0.250	0.625	0.750	1.000*
phase 4	email	cue	4.000	0.125	0.125	0.250	0.250	0.625	0.750	1.000*
phase 1	email	no cue	4.125		0.000	0.125	0.125	0.500	0.625	0.875
phase 3	collocated	cue	4.125			0.125	0.125	0.500	0.625	0.875
phase 4	chat	no cue	4.250				0.000	0.375	0.500	0.750
phase 4	vtc	no cue	4.250					0.375	0.500	0.750
phase 4	vtc	cue	4.625						0.125	0.375
phase 4	collocated	no cue	4.750							0.250

*$p < 0.05$

Appendix A.14 Multiple Comparisons and Descriptive Statistics for Subjects' Mean Understanding Response

Table A.14.1 Multiple comparisons of the mean understanding response between the phase x technology interaction

		4ch	4v	1e	2ch	1co	2co	3co	2v	4e	3v	1ch	1v	2e	3v	3ch
		4.750	4.563	4.125	4.063	4.000	4.000	4.000	3.938	3.937	3.813	3.750	3.750	3.750	3.562	3.500
4co	4.750	0.000	0.187	0.625*	0.687*	0.750*	0.750*	0.750*	0.812*	0.813*	0.937*	1.000*	1.000*	1.000*	1.188*	1.250*
4ch	4.750		0.187	0.625*	0.687*	0.750*	0.750*	0.750*	0.812*	0.813*	0.937*	1.000*	1.000*	1.000*	1.188*	1.250*
4v	4.563			0.438	0.500	0.563*	0.563*	0.563*	0.625*	0.626*	0.750*	0.813*	0.813*	0.813*	1.001*	1.063*
1e	4.125				0.062	0.125	0.125	0.125	0.187	0.188	0.312	0.375	0.375	0.375	0.563*	0.625*
2ch	4.063					0.063	0.063	0.063	0.125	0.126	0.250	0.313	0.313	0.313	0.500	0.563*
1co	4.000						0.000	0.000	0.062	0.063	0.187	0.250	0.250	0.250	0.438	0.500
2co	4.000							0.000	0.062	0.063	0.187	0.250	0.250	0.250	0.438	0.500
3co	4.000								0.062	0.063	0.187	0.250	0.250	0.250	0.438	0.500
2v	3.938									0.001	0.125	0.188	0.188	0.188	0.376	0.438
4e	3.937										0.124	0.187	0.187	0.187	0.375	0.437
3v	3.813											0.063	0.063	0.063	0.251	0.313
1ch	3.750												0.000	0.000	0.188	0.250
1v	3.750													0.000	0.188	0.250
2e	3.750														0.188	0.250
3v	3.562															0.062

*$p < 0.05$

Where co = collocated, e = email, ch = chatroom, v = video teleconferencing and the number prior to the letter(s) indicates the phase

Table A.14.2 Descriptive statistics of the understanding response for the phase x technology interaction

		N	Mean	sd
Phase 1	Collocated	8	4.000	0.632
	Email	8	4.125	0.619
	Chatroom	8	3.750	0.856
	Video Teleconferencing	8	3.750	0.683
Phase 2	Collocated	8	4.000	0.730
	Email	8	3.750	0.683
	Chatroom	8	4.063	0.680
	Video Teleconferencing	8	3.938	0.680
Phase 3	Collocated	8	4.000	0.816
	Email	8	3.813	0.750
	Chatroom	8	3.500	1.155
	Video Teleconferencing	8	3.562	1.153
Phase 4	Collocated	8	4.750	0.447
	Email	8	3.937	1.124
	Chatroom	8	4.750	0.447
	Video Teleconferencing	8	4.563	0.727

Appendix A.15 Ranked Orders

Table A.15.1 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 1

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	collocated	1	2	1	1	1	1
no cue	collocated	2	3	1	1	1	1
no cue	collocated	3	1	1	1	2	2
no cue	collocated	4	7	1	1	2	1
no cue	collocated	5	1	1	1	1	1
no cue	collocated	6	1	1	1	1	1
no cue	collocated	7	1	1	1	1	1
no cue	collocated	8	1	1	1	1	3
no cue	email	1	7	7	7	7	7
no cue	email	2	7	7	8	7	7
no cue	email	3	7	5	4	7	7
no cue	email	4	5	8	7	7	8
no cue	email	5	3	3	3	3	3
no cue	email	6	3	5	7	7	5
no cue	email	7	3	5	6	6	4
no cue	email	8	5	5	7	5	5
no cue	chatroom	1	1	3	3	2	2
no cue	chatroom	2	1	5	3	3	3
no cue	chatroom	3	6	7	8	5	8
no cue	chatroom	4	3	4	2	1	5
no cue	chatroom	5	2	2	2	2	2
no cue	chatroom	6	2	2	4	3	3
no cue	chatroom	7	4	7	5	5	3
no cue	chatroom	8	3	3	5	3	1
no cue	video teleconferencing	1	3	2	2	3	3
no cue	video teleconferencing	2	5	3	5	5	5
no cue	video teleconferencing	3	8	8	6	8	5
no cue	video teleconferencing	4	1	2	4	5	3
no cue	video teleconferencing	5	4	4	4	4	4
no cue	video teleconferencing	6	4	6	3	5	7
no cue	video teleconferencing	7	2	2	3	3	2
no cue	video teleconferencing	8	7	7	3	7	7
cue	collocated	1	5	4	4	6	4
cue	collocated	2	4	2	2	2	2
cue	collocated	3	2	2	2	1	1
cue	collocated	4	8	7	6	3	2
cue	collocated	5	5	5	5	5	5
cue	collocated	6	5	3	2	2	2
cue	collocated	7	5	3	2	2	5
cue	collocated	8	2	2	2	2	4
cue	email	1	8	8	8	8	8
cue	email	2	8	8	7	8	8
cue	email	3	4	3	3	6	4
cue	email	4	6	6	8	8	7
cue	email	5	7	7	7	7	7
cue	email	6	8	8	8	8	6

Table A.15.1 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 1 (continued)

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
cue	email	7	7	8	8	8	8
cue	email	8	6	6	8	6	6
cue	chatroom	1	6	6	6	4	6
cue	chatroom	2	2	6	4	4	4
cue	chatroom	3	3	4	7	3	3
cue	chatroom	4	4	5	3	4	6
cue	chatroom	5	6	6	6	6	6
cue	chatroom	6	6	4	5	4	4
cue	chatroom	7	8	6	7	7	7
cue	chatroom	8	4	4	6	4	2
cue	video teleconferencing	1	4	5	5	5	5
cue	video teleconferencing	2	6	4	6	6	6
cue	video teleconferencing	3	5	6	5	4	6
cue	video teleconferencing	4	2	3	5	6	4
cue	video teleconferencing	5	8	8	8	8	8
cue	video teleconferencing	6	7	7	6	6	8
cue	video teleconferencing	7	6	4	4	4	6
cue	video teleconferencing	8	8	8	4	8	8

Table A.15.2 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 2

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	collocated	1	2	1	2	1	2
no cue	collocated	2	1	1	1	1	1
no cue	collocated	3	1	1	2	1	2
no cue	collocated	4	7	1	1	5	1
no cue	collocated	5	1	1	1	1	1
no cue	collocated	6	1	1	1	1	1
no cue	collocated	7	1	1	1	1	1
no cue	collocated	8	3	5	3	3	3
no cue	email	1	7	7	7	7	7
no cue	email	2	7	7	7	7	7
no cue	email	3	7	8	7	7	7
no cue	email	4	5	7	5	7	4
no cue	email	5	3	3	3	3	3
no cue	email	6	3	5	7	7	5
no cue	email	7	6	5	7	4	6
no cue	email	8	5	3	7	5	5
no cue	chatroom	1	1	2	1	2	1
no cue	chatroom	2	3	5	5	3	3
no cue	chatroom	3	5	6	4	5	8
no cue	chatroom	4	3	3	3	1	2
no cue	chatroom	5	2	2	2	2	2
no cue	chatroom	6	2	2	4	3	3
no cue	chatroom	7	4	6	3	3	5
no cue	chatroom	8	1	1	1	1	1
no cue	video teleconferencing	1	3	3	3	3	3
no cue	video teleconferencing	2	5	3	3	5	5

Table A.15.2 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 2 (continued)

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	video teleconferencing	3	8	5	8	8	6
no cue	video teleconferencing	4	1	5	7	3	3
no cue	video teleconferencing	5	4	4	4	4	4
no cue	video teleconferencing	6	4	6	3	5	7
no cue	video teleconferencing	7	2	3	4	2	2
no cue	video teleconferencing	8	7	7	5	7	7
cue	collocated	1	5	4	4	4	6
cue	collocated	2	2	2	2	2	2
cue	collocated	3	2	2	1	2	1
cue	collocated	4	8	2	2	6	8
cue	collocated	5	5	5	5	5	5
cue	collocated	6	5	3	2	2	2
cue	collocated	7	3	2	2	6	3
cue	collocated	8	4	6	4	4	4
cue	email	1	8	8	8	8	8
cue	email	2	8	8	8	8	8
cue	email	3	6	7	5	6	5
cue	email	4	6	8	6	8	5
cue	email	5	7	7	7	7	7
cue	email	6	8	8	8	8	6
cue	email	7	7	7	8	8	8
cue	email	8	6	4	8	6	6
cue	chatroom	1	6	5	5	5	4
cue	chatroom	2	4	6	6	4	4
cue	chatroom	3	3	4	3	3	3
cue	chatroom	4	4	4	4	2	6
cue	chatroom	5	6	6	6	6	6
cue	chatroom	6	6	4	5	4	4
cue	chatroom	7	8	8	6	7	7
cue	chatroom	8	2	2	2	2	2
cue	video teleconferencing	1	4	6	6	6	5
cue	video teleconferencing	2	6	4	4	6	6
cue	video teleconferencing	3	4	3	6	4	4
cue	video teleconferencing	4	2	6	8	4	7
cue	video teleconferencing	5	8	8	8	8	8
cue	video teleconferencing	6	7	7	6	6	8
cue	video teleconferencing	7	5	4	5	5	4
cue	video teleconferencing	8	8	8	6	8	8

Table A.15.3 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 3

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	collocated	1	3	1	3	1	2
no cue	collocated	2	3	3	3	1	1
no cue	collocated	3	2	1	2	1	1
no cue	collocated	4	1	1	3	1	1
no cue	collocated	5	1	1	1	1	1
no cue	collocated	6	1	1	1	1	1
no cue	collocated	7	1	1	1	1	2
no cue	collocated	8	3	7	3	3	5
no cue	email	1	7	7	7	7	7
no cue	email	2	7	7	7	7	7
no cue	email	3	8	8	8	8	8
no cue	email	4	3	3	5	7	8
no cue	email	5	3	3	3	3	3
no cue	email	6	7	7	5	7	5
no cue	email	7	8	4	8	8	4
no cue	email	8	5	3	5	5	3
no cue	chatroom	1	1	2	1	2	1
no cue	chatroom	2	1	1	1	3	3
no cue	chatroom	3	6	6	6	5	7
no cue	chatroom	4	2	2	1	2	3
no cue	chatroom	5	2	2	2	2	2
no cue	chatroom	6	2	3	4	2	3
no cue	chatroom	7	3	3	5	5	3
no cue	chatroom	8	1	1	1	1	1
no cue	video teleconferencing	1	2	3	2	3	3
no cue	video teleconferencing	2	5	5	5	5	5
no cue	video teleconferencing	3	5	5	4	6	5
no cue	video teleconferencing	4	4	5	2	3	5
no cue	video teleconferencing	5	4	4	4	4	4
no cue	video teleconferencing	6	5	5	3	4	7
no cue	video teleconferencing	7	2	2	2	2	1
no cue	video teleconferencing	8	7	5	7	7	7
cue	collocated	1	4	4	4	6	4
cue	collocated	2	4	4	4	2	2
cue	collocated	3	1	2	1	2	2
cue	collocated	4	7	8	4	6	2
cue	collocated	5	5	5	5	5	5
cue	collocated	6	3	2	2	3	2
cue	collocated	7	4	5	3	3	6
cue	collocated	8	4	8	4	4	6
cue	email	1	8	8	8	8	8
cue	email	2	8	8	8	8	8
cue	email	3	7	7	7	7	6
cue	email	4	8	4	6	8	7
cue	email	5	7	7	7	7	7
cue	email	6	8	8	8	8	6
cue	email	7	7	8	7	7	8
cue	email	8	6	4	6	6	4
cue	chatroom	1	5	5	5	5	6

*Incomplete data point

Table A.15.3 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 3 (continued)

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
cue	chatroom	2	2	2	2	4	4
cue	chatroom	3	3	3	5	3	4
cue	chatroom	4	6	7	7	5	4
cue	chatroom	5	6	6	6	6	6
cue	chatroom	6	4	4	6	5	4
cue	chatroom	7	6	7	6	6	7
cue	chatroom	8	2	2	2	2	2
cue	video teleconferencing	1	6	6	6	4	5
cue	video teleconferencing	2	6	6	6	6	6
cue	video teleconferencing	3	4	4	3	4	3
cue	video teleconferencing	4	5	6	8	4	6
cue	video teleconferencing	5	8	8	8	8	8
cue	video teleconferencing	6	6	6	7	6	8
cue	video teleconferencing	7	5	6	4	4	5
cue	video teleconferencing	8	8	6	8	8	8

*Incomplete data point

Table A.15.4 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 4

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	collocated	1	2	1	2	2	2
no cue	collocated	2	3	3	3	1	1
no cue	collocated	3	1	1	1	1	1
no cue	collocated	4	1	1	1	2	4
no cue	collocated	5	1	1	1	1	1
no cue	collocated	6	1	1	1	1	1
no cue	collocated	7	1	1	1	1	1
no cue	collocated	8	3	5	1	3	3
no cue	email	1	7	7	7	7	7
no cue	email	2	7	7	7	7	7
no cue	email	3	8	8	8	8	8
no cue	email	4	3	4	3	3	2
no cue	email	5	3	3	3	3	3
no cue	email	6	7	7	5	6	6
no cue	email	7	4	4	4	4	3
no cue	email	8	5	3	5	5	5
no cue	chatroom	1	1	2	1	1	1
no cue	chatroom	2	1	1	1	3	3
no cue	chatroom	3	7	4	5	6	7
no cue	chatroom	4	2	3	2	4	1
no cue	chatroom	5	2	2	2	2	2
no cue	chatroom	6	3	3	4	2	3
no cue	chatroom	7	3	3	3	3	4
no cue	chatroom	8	1	1	3	1	1
no cue	video teleconferencing	1	3	3	3	3	3
no cue	video teleconferencing	2	5	5	5	5	5
no cue	video teleconferencing	3	5	7	6	5	4
no cue	video teleconferencing	4	4	5	4	1	3
no cue	video teleconferencing	5	4	4	4	4	4

*Incomplete data point

Table A.15.4 Satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders in phase 4 (continued)

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	video teleconferencing	6	5	5	3	5	5
no cue	video teleconferencing	7	2	2	2	2	2
no cue	video teleconferencing	8	7	7	7	7	7
cue	collocated	1	4	4	4	4	4
cue	collocated	2	4	4	4	2	2
cue	collocated	3	2	2	2	2	2
cue	collocated	4	8	2	8	7	5
cue	collocated	5	5	5	5	5	5
cue	collocated	6	2	2	2	3	2
cue	collocated	7	5	5	5	5	5
cue	collocated	8	4	6	2	4	4
cue	email	1	8	8	8	8	8
cue	email	2	8	8	8	8	8
cue	email	3	6	6	7	7	6
cue	email	4	7	7	7	6	6
cue	email	5	7	7	7	7	7
cue	email	6	8	8	8	8	8
cue	email	7	8	8	8	8	7
cue	email	8	6	4	6	6	6
cue	chatroom	1	5	5	5	5	5
cue	chatroom	2	2	2	2	4	4
cue	chatroom	3	4	3	4	4	5
cue	chatroom	4	5	6	5	8	7
cue	chatroom	5	6	6	6	6	6
cue	chatroom	6	4	4	6	4	4
cue	chatroom	7	7	7	7	7	8
cue	chatroom	8	2	2	4	2	2
cue	video teleconferencing	1	6	6	6	6	6
cue	video teleconferencing	2	6	6	6	6	6
cue	video teleconferencing	3	3	5	3	3	3
cue	video teleconferencing	4	6	8	6	5	8
cue	video teleconferencing	5	8	8	8	8	8
cue	video teleconferencing	6	6	6	7	7	7
cue	video teleconferencing	7	6	6	6	6	6
cue	video teleconferencing	8	8	8	8	8	8

*Incomplete data point

Table A.15.5 Overall satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
no cue	collocated	1	2	1	2	1	2
no cue	collocated	2	1	1	1	1	1
no cue	collocated	3	1	1	1	1	1
no cue	collocated	4	8	1	1	7	1
no cue	collocated	5	1	1	1	1	1
no cue	collocated	6	1	1	1	1	1
no cue	collocated	7	1	1	1	1	1
no cue	collocated	8	3	3	3	3	3
no cue	email	1	7	7	7	7	7
no cue	email	2	7	7	7	7	7
no cue	email	3	8	8	8	8	8
no cue	email	4	6	3	3	3	4
no cue	email	5	3	3	3	3	3
no cue	email	6	7	7	5	6	6
no cue	email	7	4	4	4	4	4
no cue	email	8	5	4	5	5	5
no cue	chatroom	1	1	2	1	2	1
no cue	chatroom	2	3	5	3	3	5
no cue	chatroom	3	6	7	6	7	6
no cue	chatroom	4	3	4	4	1	2
no cue	chatroom	5	2	2	2	2	2
no cue	chatroom	6	3	3	4	2	3
no cue	chatroom	7	3	3	3	3	3
no cue	chatroom	8	1	1	1	1	1
no cue	video teleconferencing	1	3	3	3	3	3
no cue	video teleconferencing	2	5	3	5	5	3
no cue	video teleconferencing	3	7	5	5	6	5
no cue	video teleconferencing	4	1	2	2	5	3
no cue	video teleconferencing	5	4	4	4	4	4
no cue	video teleconferencing	6	5	5	3	5	5
no cue	video teleconferencing	7	2	2	2	2	2
no cue	video teleconferencing	8	7	7	7	7	7
cue	collocated	1	6	5	5	5	6
cue	collocated	2	2	2	2	2	2
cue	collocated	3	2	2	2	2	2
cue	collocated	4	7	8	6	8	6
cue	collocated	5	5	5	5	5	5
cue	collocated	6	2	2	2	3	2
cue	collocated	7	5	5	5	5	5
cue	collocated	8	4	6	4	4	4
cue	email	1	8	8	8	8	8
cue	email	2	8	8	8	8	8
cue	email	3	5	6	7	5	7
cue	email	4	5	7	5	4	5
cue	email	5	7	7	7	7	7
cue	email	6	8	8	8	8	8
cue	email	7	8	8	8	8	8
cue	email	8	6	5	6	6	6
cue	chatroom	1	4	4	4	4	4

*Incomplete data point

Table A.15.5 Overall satisfaction, ease of use, efficiency, effectiveness, and comfort ranked orders (continued)

Feedback Cue Level	Technology Level	Subject	Satisfaction	Ease of Use	Time	Effective	Comfort
cue	chatroom	2	4	6	4	4	6
cue	chatroom	3	4	4	3	3	4
cue	chatroom	4	4	5	7	2	7
cue	chatroom	5	6	6	6	6	6
cue	chatroom	6	4	4	6	4	4
cue	chatroom	7	7	7	7	7	7
cue	chatroom	8	2	2	2	2	2
cue	video teleconferencing	1	5	6	6	6	5
cue	video teleconferencing	2	6	4	6	6	4
cue	video teleconferencing	3	3	3	4	4	3
cue	video teleconferencing	4	2	6	8	6	8
cue	video teleconferencing	5	8	8	8	8	8
cue	video teleconferencing	6	6	6	7	7	7
cue	video teleconferencing	7	6	6	6	6	6
cue	video teleconferencing	8	8	8	8	8	8

*Incomplete data point

Appendix A.16 Correlation between Subjective Ranks

Table A.16.1 Pearson product moment for satisfaction, ease of use, efficiency, effectiveness and comfort ranks

	Ease of Use	Efficiency	Effectiveness	Comfort
Satisfaction	0.805	0.788	0.858	0.810
Ease of Use		0.802	0.809	0.819
Efficiency			0.831	0.777
Effectiveness				0.850

Table A.16.2 Pearson product moment for overall satisfaction, ease of use, efficiency, effectiveness, and comfort ranks

	Ease of Use	Efficiency	Effectiveness	Comfort
Satisfaction	0.830	0.804	0.905	0.807
Ease of Use		0.914	0.848	0.946
Efficiency			0.836	0.946
Effectiveness				0.842

Appendix A.17 Analysis of Ease of Use, Efficiency, Effectiveness, and Comfort Ranks

Appendix A.17.1 Technology

Ease of Use Ranks

Table A.17.1 Summary of Friedman's test results for technology ease of use ranks

	df	S	p-value
Phase 1	3	13.73	0.003**
Phase 2	3	12.87	0.005**
Phase 3	3	8.81	0.032*
Phase 4	3	15.45	0.002**
Overall	3	13.68	0.004**

*p < 0.05
**p < 0.01

Table A.17.2 Summary of technology level's mean ease of use rank and standard deviation

		Collocated	Email	Chatroom	Video Teleconferencing
Phase 1	mean	1.125	3.375	2.687	2.812
	sd	0.354	0.694	0.594	1.193
Phase 2	mean	1.250	3.437	2.375	2.938
	sd	0.707	0.729	0.916	0.863
Phase 3	mean	1.688	3.250	2.000	3.063
	sd	1.100	1.165	0.707	0.678
Phase 4	mean	1.375	3.500	1.875	3.250
	sd	0.744	0.756	0.641	0.707
Overall	mean	1.438	3.687	2.125	2.750
	sd	0.678	0.594	0.694	1.035

Phase 1:

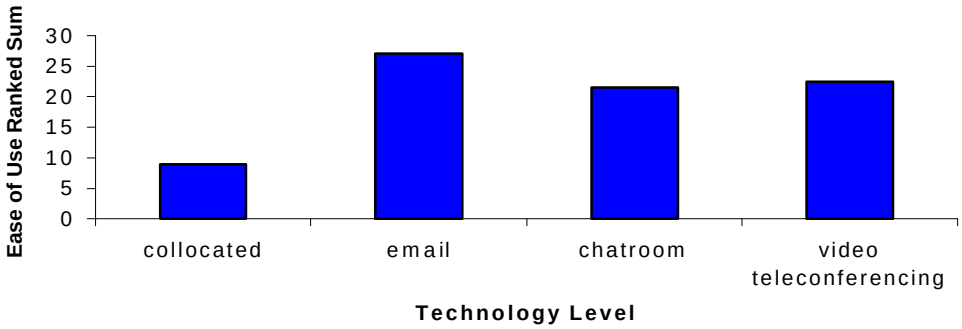


Figure A.17.1 Ease of use ranked sums for technology levels in phase 1

Table A.17.3 Multiple comparisons between ease of use ranked sums for technology levels in phase 1

	ranked sum	Chatroom 21.5	Video Teleconferencing 22.5	Email 27.0
	ranked sum			
Collocated	9.0	12.5*	13.5*	18.0*
Chatroom	21.5		1.0	5.5
Video Teleconferencing	22.5			4.5

*p < 0.01

Phase 2:

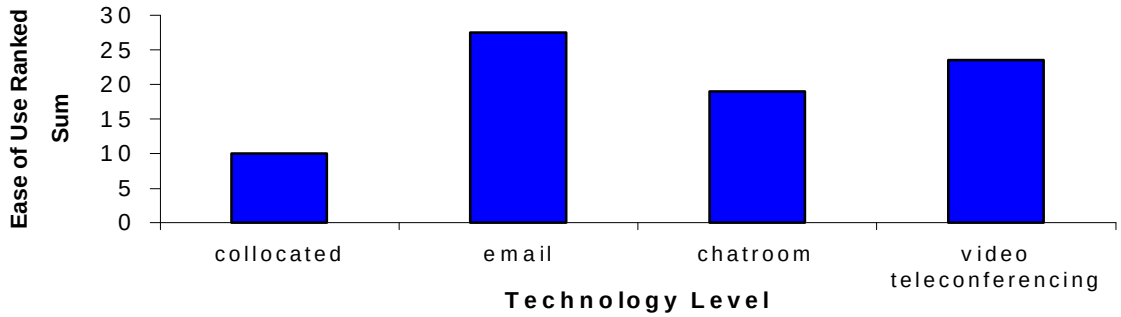


Figure A.17.2 Comparison of the ease of use ranked sums for technology levels in phase 2

Table A.17.4 Multiple comparisons between ease of use ranked sums for technology levels in phase 2

	ranked sum	Chatroom 19.0	Video Teleconferencing 23.5	Email 27.5
	ranked sum			
Collocated	10.0	9.0	13.5*	17.5*
Chatroom	19.0		4.5	8.5
Video Teleconferencing	23.5			4.0

*p < 0.01

Phase 3:

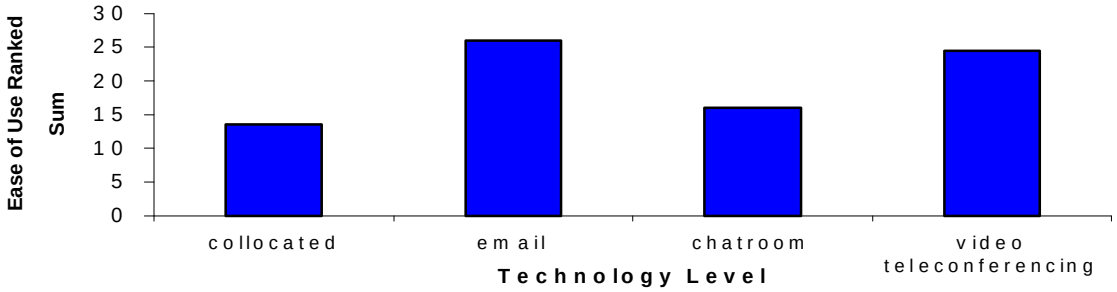


Figure A.17.3 Comparison of the ease of use ranked sums for technology levels in phase 3

Table A.17.5 Multiple comparisons between ease of use ranked sums for technology levels in phase 3

	ranked sum	Chatroom 16.0	Video Teleconferencing 24.5	Email 26.0
	ranked sum			
Collocated	13.5	2.5	11.0*	12.5**
Chatroom	16.0		8.5	10.0*
Video Teleconferencing	24.5			1.5

*p < 0.05
**p < 0.01

Phase 4:

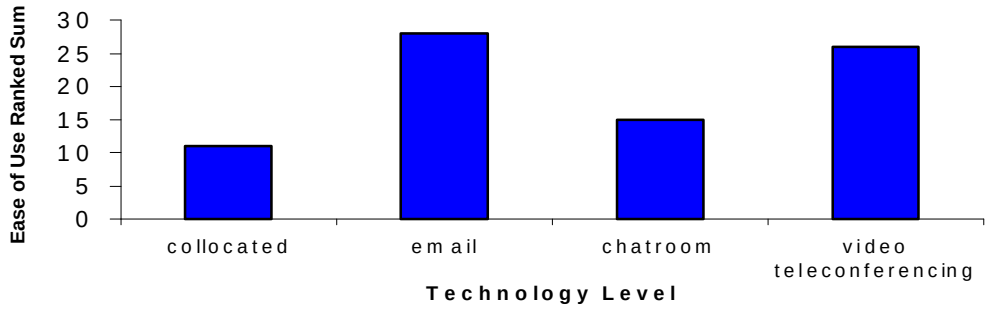


Figure A.17.4 Comparison of the ease of use ranked sums for technology levels in phase 4

Table A.17.6 Multiple comparisons of ease of use ranked sums for technology levels in phase 4

	ranked sum	Chatroom 15.0	Video Teleconferencing 26.0	Email 28.0
	ranked sum			
Collocated	11.0	4.0	15.0**	17.0**
Chatroom	15.0		11.0*	13.0**
Video Teleconferencing	26.0			2.0

*p < 0.05
**p < 0.01

Overall:

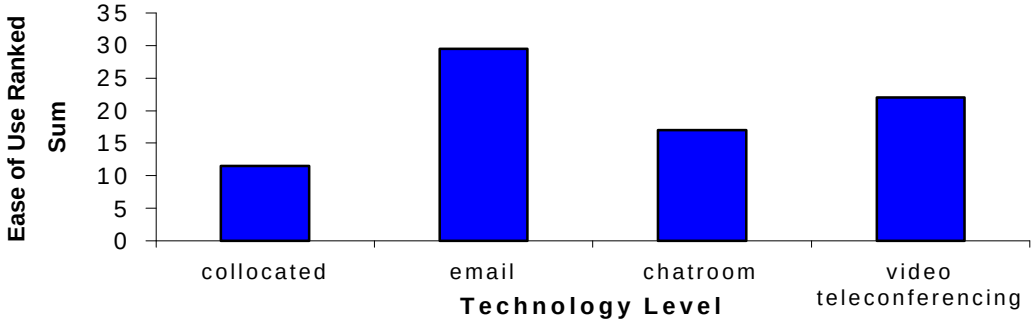


Figure A.17.5 Overall ease of use ranked sums for technology levels

Table A.17.7 Multiple comparisons between overall ease of use ranked sums for technology levels

	ranked sum	Chatroom 17.0	Video Teleconferencing 22.0	Email 29.5
	ranked sum			
Collocated	11.5	5.5	10.5*	18.0**
Chatroom	17.0		5.0	12.5**
Video Teleconferencing	22.0			7.5

*p < 0.05
**p < 0.01

Efficiency Ranks

Table A.17.8 Summary of Friedman's test results for technology efficiency ranks

	df	S	p-value
Phase 1	3	16.82	0.001*
Phase 2	3	17.81	0.001*
Phase 3	3	16.22	0.001*
Phase 4	3	17.65	0.001*
Overall	3	14.15	0.003*

*p < 0.01

Table A.17.9 Summary of technology level's mean efficiency rank and standard deviation

		Collocated	Email	Chatroom	Video Teleconferencing
Phase 1	mean	1.125	3.750	2.562	2.562
	sd	0.354	0.707	0.904	0.496
Phase 2	mean	1.187	3.625	2.063	3.125
	sd	0.372	0.518	0.623	0.791
Phase 3	mean	1.375	3.750	1.938	2.938
	sd	0.518	0.463	0.863	0.776
Phase 4	mean	1.250	3.687	2.000	3.063
	sd	0.463	0.458	0.707	0.729
Overall	mean	1.250	3.500	2.250	3.000
	sd	0.463	0.756	1.000	0.707

Phase 1:

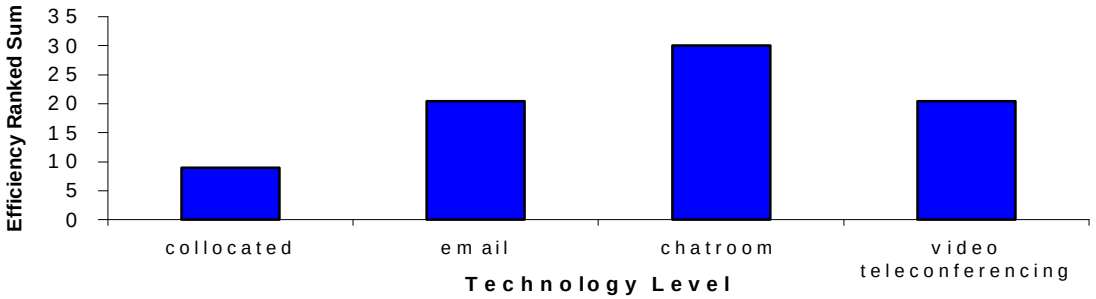


Figure A.17.6 Efficiency ranked sum for each technology level in phase 1

Table A.17.10 Multiple comparisons of efficiency ranked sums for technology levels in phase 1

	ranked sum	Chatroom 20.5	Video Teleconferencing 20.5	Email 30.0
	ranked sum			
Collocated	9.0	11.5*	11.5*	21.0**
Chatroom	20.5		0.0	9.5*
Video Teleconferencing	20.5			9.5*

*p < 0.05
**p < 0.01

Phase 2:

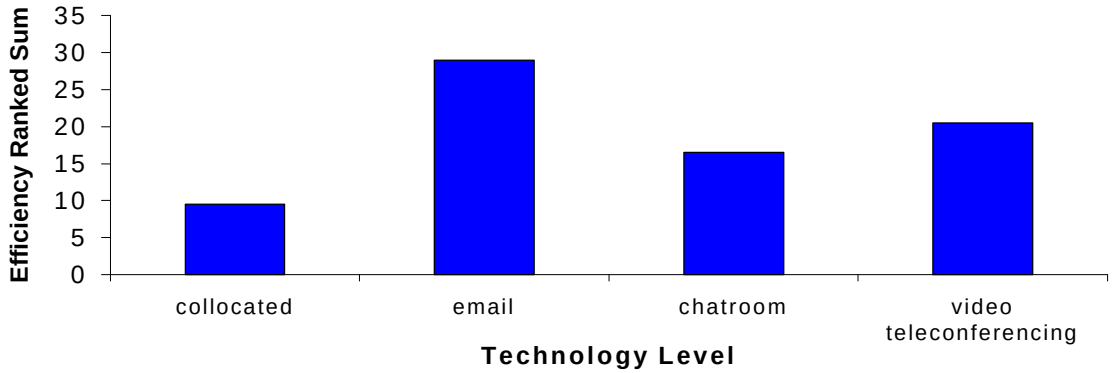


Figure A.17.7 Efficiency ranked sum for each technology level in phase 2

Table A.17.11 Multiple comparisons of efficiency ranked sums for technology levels in phase 2

	ranked sum	Chatroom	Video Teleconferencing	Email
	ranked sum	16.5	20.5	29.0
Collocated	9.5	7.0	11.0*	19.5**
Chatroom	16.5		4.0	12.5**
Video Teleconferencing	25.0			4.0

*p < 0.05
**p < 0.01

Phase 3:

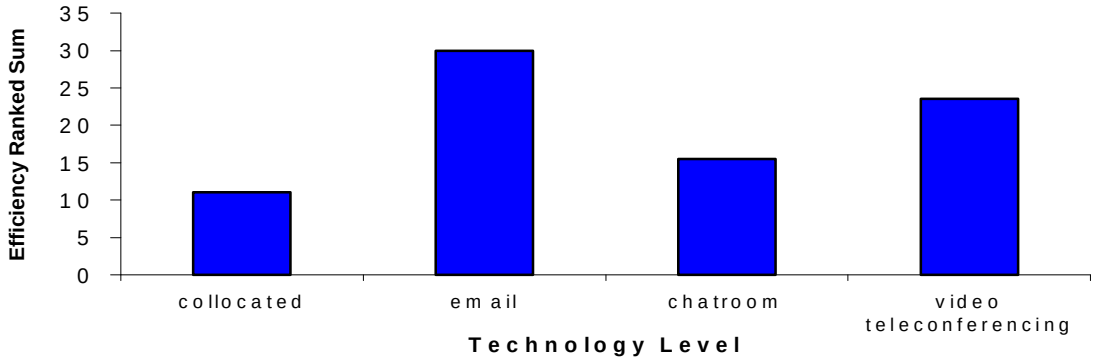


Figure A.17.8 Efficiency ranked sums for technology levels in phase 3

Table A.17.12 Multiple comparisons of efficiency ranked sums for technology levels in phase 3

	ranked sum	Chatroom	Video Teleconferencing	Email
	ranked sum	15.5	23.5	30.0
Collocated	11.0	4.5	12.5*	19.0*
Chatroom	15.5		8.0	14.5*
Video Teleconferencing	23.5			6.5

*p < 0.01

Phase 4:

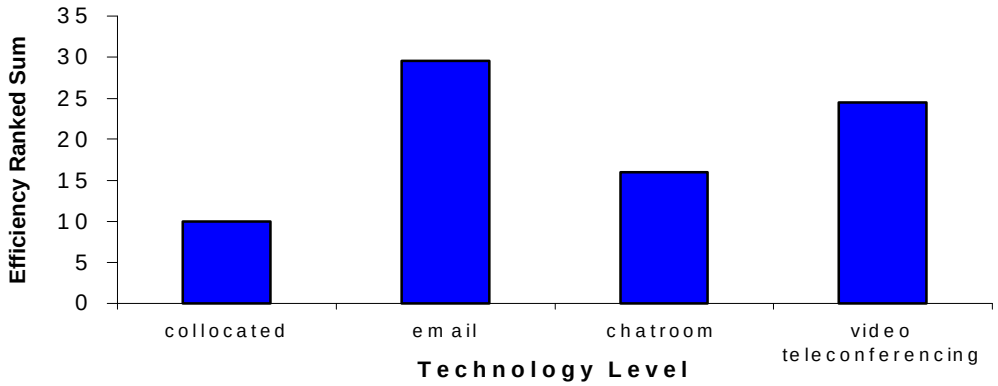


Figure A.17.9 Efficiency ranked sum for each technology level in phase 4

Table A.17.13 Multiple comparisons of efficiency ranked sums for technology levels in phase 4

		Chatroom	Video Teleconferencing	Email
	ranked sum	16.0	24.5	29.5
	ranked sum			
Collocated	10.0	6.0	14.5*	19.5*
Chatroom	16.0		8.5	13.5*
Video Teleconferencing	24.5			5.0

*p < 0.01

Overall:

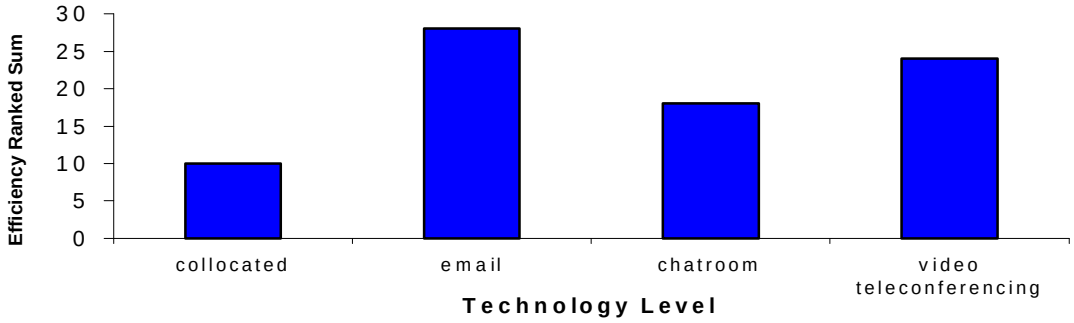


Figure A.17.10 Overall efficiency ranked sums for technology levels

Table A.17.14 Multiple comparisons of the overall efficiency ranked sums for technology levels

		Chatroom	Video Teleconferencing	Email
	ranked sum	18.0	24.0	28.0
	ranked sum			
Collocated	10.0	8.0	14.0**	18.0**
Chatroom	18.0		6.0	10.0*
Video Teleconferencing	24.0			4.0

*p < 0.05
**p < 0.01

Effectiveness Ranks

Table A.17.15 Summary of Friedman's test results for technology effectiveness ranks

	df	S	p-value
Phase 1	3	19.54	<0.001*
Phase 2	3	15.91	0.001*
Phase 3	3	17.17	0.001*
Phase 4	3	12.27	0.007*
Overall	3	12.73	0.005*

*p < 0.01

Table A.17.16 Summary of technology levels' mean effectiveness rank and standard deviation

		Collocated	Email	Chatroom	Video Teleconferencing
Phase 1	mean	1.063	3.500	1.938	3.125
	sd	0.177	0.756	0.563	0.641
Phase 2	mean	1.438	3.750	1.875	2.938
	sd	0.729	0.463	0.641	0.863
Phase 3	mean	1.375	3.750	2.000	2.875
	sd	0.518	0.463	0.535	0.835
Phase 4	mean	1.375	3.563	2.312	2.750
	sd	0.582	0.623	0.961	1.035
Overall	mean	1.562	3.500	1.875	3.063
	sd	1.050	0.756	0.694	0.678

Phase 1:

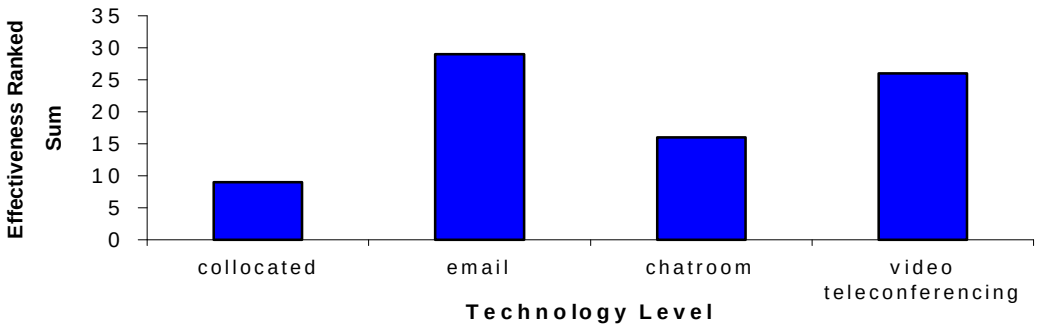


Figure A.17.11 Effectiveness ranked sum for technology levels in phase 1

Table A.17.17 Phase 1 multiple comparisons of effectiveness ranked sums for technology levels

	ranked sum	Chatroom 16.0	Video Teleconferencing 26.0	Email 29.0
Collocated	9.0	7.0	17.0**	20.0**
Chatroom	16.0		10.0*	13.0**
Video Teleconferencing	26.0			20.0**

*p < 0.05
**p < 0.01

Phase 2:

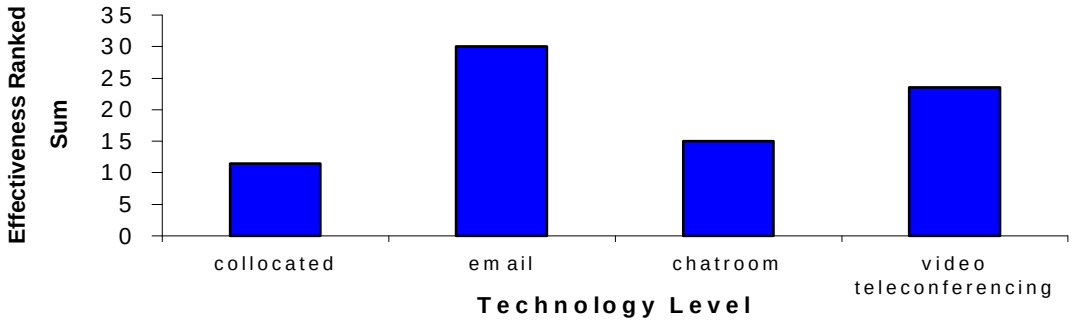


Figure A.17.12 Effectiveness ranked sums for technology levels in phase 2

Table A.17.18 Multiple comparisons between effectiveness ranked sums for technology levels in phase 2

		Chatroom	Video Teleconferencing	Email
	ranked sum	15.0	23.5	30.0
	ranked sum			
Collocated	11.5	4.5	12.0*	18.5**
Chatroom	15.0		8.5	15.0**
Video Teleconferencing	23.5			6.5

*p < 0.01

Phase 3:

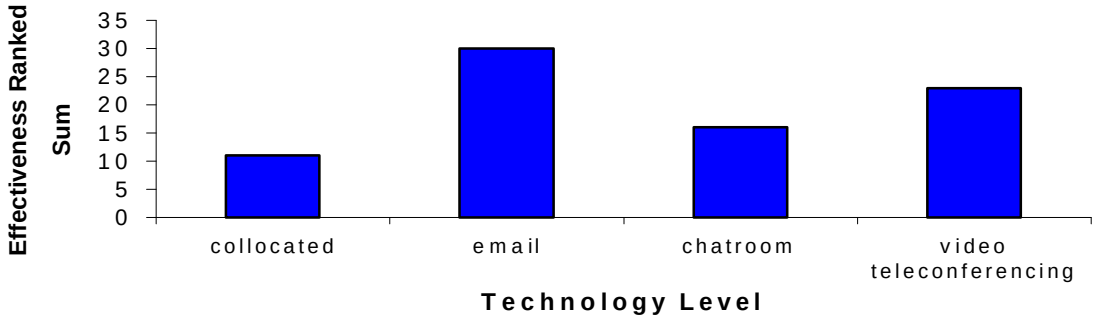


Figure A.17.13 Effectiveness ranked sums for technology levels in phase 3

Table A.17.19 Multiple comparisons of effectiveness ranked sums for technology levels in phase 3

		Chatroom	Video Teleconferencing	Email
	ranked sum	16.0	23.0	30.0
	ranked sum			
Collocated	11.0	5.0	12.0*	19.0**
Chatroom	16.0		7.0	14.0**
Video Teleconferencing	23.0			7.0

*p < 0.05
**p < 0.01

Phase 4:

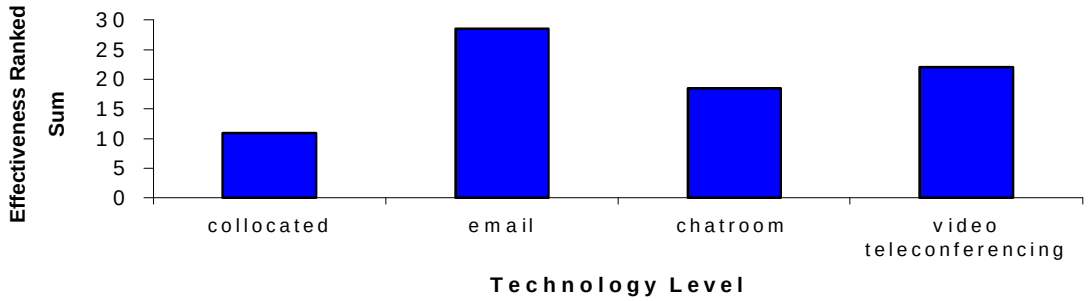


Figure A.17.14 Comparison of the effectiveness ranked sums for technology levels in phase 4

Table A.17.20 Multiple comparisons of effectiveness ranked sums for technology levels in phase 4

		Chatroom	Video Teleconferencing	Email
	ranked sum	18.5	22.0	28.5
	ranked sum			
Collocated	11.0	7.5	11.0*	17.5**
Chatroom	18.5		3.5	10.0*
Video Teleconferencing	22.0			6.5

*p < 0.05
**p < 0.01

Overall:

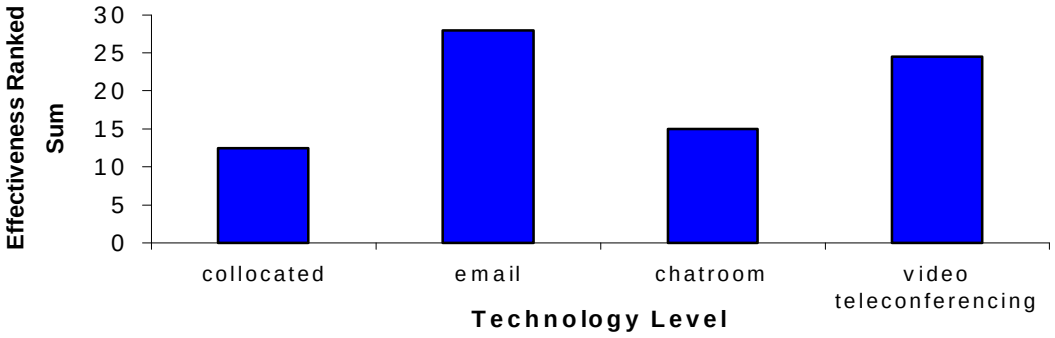


Figure A.17.15 Overall effectiveness ranked sums for technology levels

Table A.17.21 Multiple comparisons between the overall effectiveness ranked sums for technology levels

		Chatroom	Video Teleconferencing	Email
	ranked sum	15.0	24.5	28.0
	ranked sum			
Collocated	12.5	2.5	12.0*	15.5**
Chatroom	15.0		9.5*	13.0**
Video Teleconferencing	24.5			3.5

*p < 0.05
**p < 0.01

Comfort Ranks

Table A.17.22 Summary of Friedman's test results for technology comfort ranks

	df	S	P
Phase 1	3	16.60	0.001**
Phase 2	3	13.50	0.004**
Phase 3	3	12.75	0.005**
Phase 4	3	11.42	0.010*
Overall	3	13.92	0.003**

*p < 0.05
**p < 0.01

Table A.17.23 Summary of technology levels' mean comfort rank and standard deviation

		Collocated	Email	Chatroom	Video Teleconferencing
Phase 1	mean	1.125	3.500	2.312	3.063
	sd	0.354	0.535	0.704	0.863
Phase 2	mean	1.500	3.437	1.875	3.187
	sd	0.707	0.623	0.835	0.923
Phase 3	mean	1.375	3.500	2.125	3.000
	sd	0.744	0.756	0.641	1.069
Phase 4	mean	1.438	3.312	2.125	3.125
	sd	0.729	0.884	0.954	0.835
Overall	mean	1.312	3.563	2.187	2.938
	sd	0.594	0.623	0.843	0.943

Phase 1:

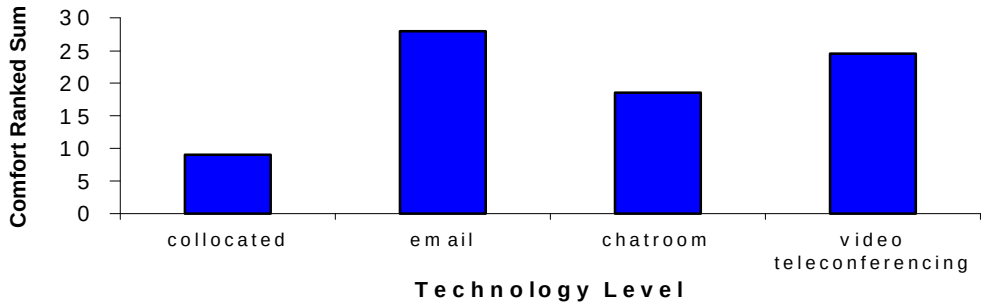


Figure A.17.16 Comfort ranked sums for technology levels in phase 1

Table A.17.24 Phase 1 multiple comparisons between comfort ranked sums of technology levels

	ranked sum	Chatroom 18.5	Video Teleconferencing 24.5	Email 28.0
	ranked sum			
Collocated	9.0	9.5*	15.5**	19.0**
Chatroom	18.5		6.0	9.5*
Video Teleconferencing	24.5			3.5

*p < 0.05
**p < 0.01

Phase 2:

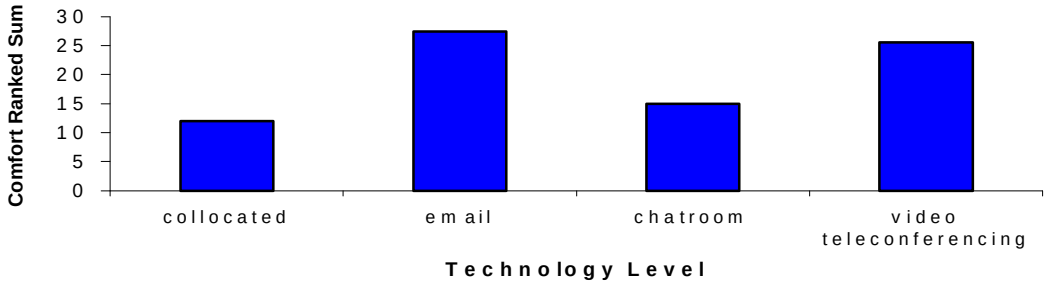


Figure A.17.17 Comparison of the comfort ranked sums for technology levels in phase 2

Table A.17.25 Multiple comparisons of comfort ranked sums for technology levels in phase 2

	ranked sum	Chatroom 15.0	Video Teleconferencing 25.5	Email 27.5
	ranked sum			
Collocated	12.0	3.0	13.5**	15.5**
Chatroom	15.0		10.5*	12.5**
Video Teleconferencing	25.5			2.0

*p < 0.05
**p < 0.01

Phase 3:

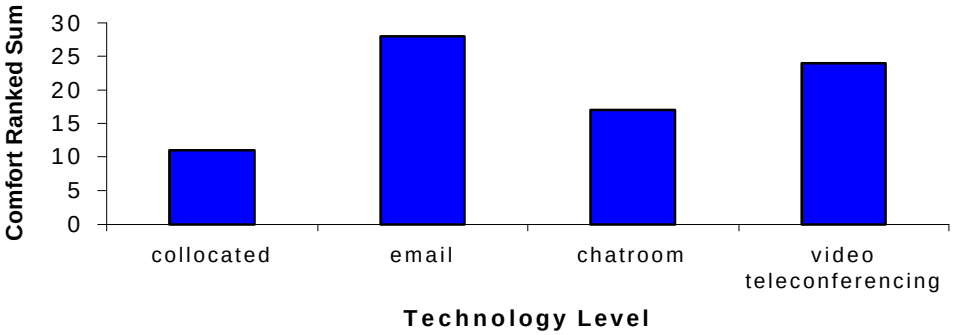


Figure A.17.18 Comfort ranked sums for technology levels in phase 3

Table A.17.26 Multiple comparisons of comfort ranked sums for technology levels in phase 3

		Chatroom	Video Teleconferencing	Email
	ranked sum	17.0	24.0	28.0
	ranked sum			
Collocated	11.0	6.0	13.0**	17.0**
Chatroom	17.0		7.0	11.0*
Video Teleconferencing	24.0			4.0

*p < 0.05
**p < 0.01

Phase 4:

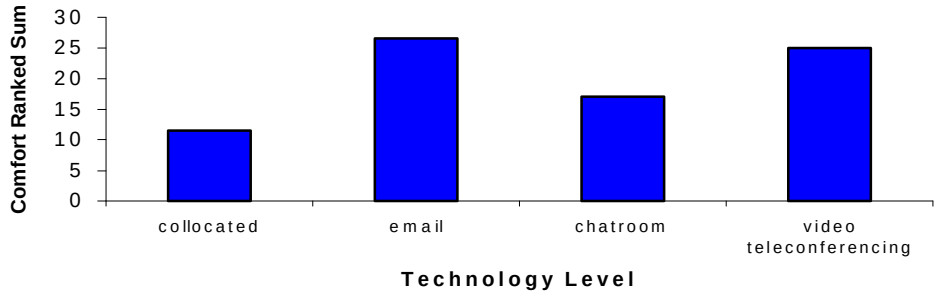


Figure A.17.19 Comfort ranked sums for technology levels in phase 4

Table A.17.27 Multiple comparisons of comfort ranked sums for technology levels in phase 4

		Chatroom	Video Teleconferencing	Email
	ranked sum	17.0	25.0	26.5
	ranked sum			
Collocated	11.5	5.5	13.5**	15.0**
Chatroom	17.0		8.0	9.5*
Video Teleconferencing	25.0			1.5

*p < 0.05
**p < 0.01

Overall:

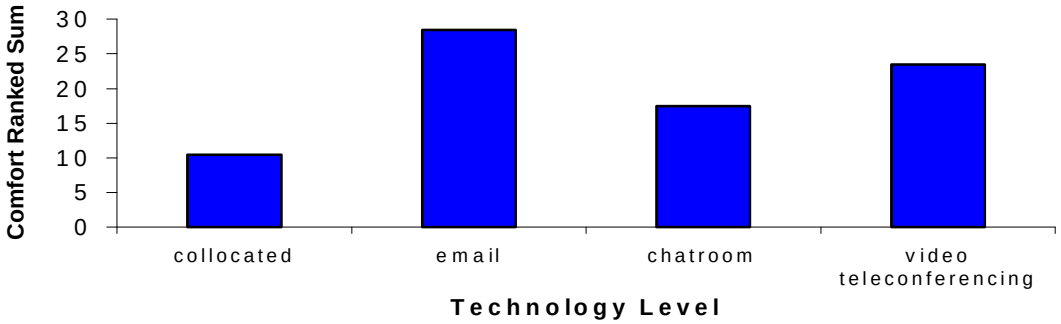


Figure A.17.20 Overall comfort ranked sums for technology levels

Table A.17.28 Multiple comparisons of overall comfort ranked sums for technology levels

	ranked sum	Chatroom 17.5	Video Teleconferencing 23.5	Email 28.5
	ranked sum			
Collocated	10.5	7.0	13.0**	18.0**
Chatroom	17.5		6.0	11.0*
Video Teleconferencing	23.5			5.0

*p < 0.05
**p < 0.01

Appendix A.17.2 Feedback Cue

Table A.17.29 Summary of Friedman's test results for feedback cue ease of use, efficiency, effectiveness, and comfort ranks[1]

	df	S	P
Phase 1	1	4.5	0.034*
Phase 2	1	4.5	0.034*
Phase 3	1	4.5	0.034*
Phase 4	1	4.5	0.034*
Overall	1	4.5	0.034*

*$p < 0.05$

[1]The results are the same for ease of use, efficiency, effectiveness, and comfort.

Table A.17.30 Summary of feedback cue levels' mean satisfaction rank and standard deviation[2]

		Mean	Standard Deviation
Phase 2	No Cue	1.125	0.354
	Cue	1.875	0.354
Phase 3	No Cue	1.125	0.354
	Cue	1.875	0.354
Phase 4	No Cue	1.125	0.354
	Cue	1.875	0.354
Overall	No Cue	1.187	0.372
	Cue	1.813	0.372

[2]The means and standard deviations are the same for ease of use, efficiency, effectiveness, and comfort.

Appendix A.17.3 Interaction between Feedback Cue and Technology

Ease of Use Ranks

Table A.17.31 ANOVA summary table for ease of use ranks in phase 1

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	36.000	36.000	7.412	0.030*
CxS	7	34.000	4.857		
T	3	129.875	43.292	8.408	0.001**
TxS	21	108.125	5.149		
CxT	3	5.625	1.875	1.761	0.186
CxTxS	21	22.375	1.065		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.32 ANOVA summary table for ease of use ranks in phase 2

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	36.000	36.000	8.690	0.021*
CxS	7	29.000	4.143		
T	3	137.000	45.667	7.492	0.001**
TxS	21	128.000	6.095		
CxT	3	0.500	0.167	0.637	0.600
CxTxS	21	5.500	0.262		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.33 ANOVA summary table for ease of use ranks in phase 3

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	64.000	64.000	9.956	0.016*
CxS	7	45.000	6.429		
T	3	78.500	26.167	4.243	0.017*
TxS	21	129.500	6.167		
CxT	3	3.500	1.167	1.581	0.224
CxTxS	21	15.500	0.738		
Total	63	336.000			

*p < 0.05

Table A.17.34 ANOVA summary table for ease of use ranks in phase 4

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	56.250	56.250	9.663	0.017*
CxS	7	40.750	5.821		
T	3	137.375	45.792	9.663	0.000**
TxS	21	95.625	4.554		
CxT	3	0.375	0.125	0.467	0.709
CxTxS	21	5.625	0.270		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.35 ANOVA summary table for the overall ease of use ranks

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	68.063	68.063	8.916	0.020*
CxS	7	53.438	7.634		
T	3	99.875	33.2917	7.198	0.002**
TxS	21	97.125	4.625		
CxT	3	6.813	2.271	4.462	0.014*
CxTxS	21	9.688	0.461		
Total	63	335.002			

*p < 0.05
**p < 0.01

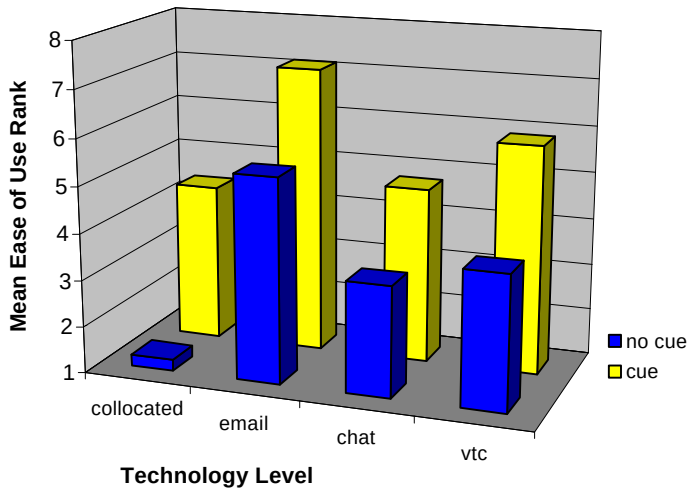


Figure A.17.21 Overall ease of use ranked sums for the technology x feedback cue interaction

Table A.17.36 Multiple comparisons of the overall ease of use ranked sums for the technology x feedback cue interaction

	mean	Chatroom No Cue 3.375	VTC No Cue 3.875	Collocated Cue 4.375	Chatroom Cue 4.750	Email No Cue 5.375	VTC Cue 5.875	Email Cue 7.125
Collocated No Cue	1.250	2.125*	2.625*	3.125*	3.500*	4.125*	4.625*	5.875*
Chatroom No Cue	3.375		0.500	1.000	1.375	2.000*	2.500*	3.750*
VTC No Cue	3.875			0.500	0.875	1.500	2.000*	3.250*
Collocated Cue	4.375				0.375	1.000	1.500	2.750*
Chatroom Cue	4.750					0.625	1.125	2.375*
Email No Cue	5.375						0.500	1.750*
VTC Cue	5.875							1.250

*p < 0.05

Table A.17.37 Descriptive statistics for the overall ease of use ranks for the experimental conditions

		N	Mean	sd
Collocated	No Cue	8	1.250	0.707
	Cue	8	4.375	2.200
Email	No Cue	8	5.375	2.066
	Cue	8	7.125	1.126
Chatroom	No Cue	8	3.375	1.923
	Cue	8	4.475	1.581
Video	No Cue	8	3.875	1.727
Teleconferencing	Cue	8	5.875	1.727

Efficiency Ranks

Table A.17.38 ANOVA summary table for efficiency ranks in phase 1

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	39.063	39.063	10.749	0.014*
CxS	7	25.438	3.634		
T	3	168.375	56.125	13.005	<0.001**
TxS	21	90.625	4.136		
CxT	3	2.563	0.854	1.805	0.177
CxTxS	21	9.938	0.473		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.39 ANOVA summary table for efficiency ranks in phase 2

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	30.250	30.250	6.274	0.041*
CxS	7	33.750	4.821		
T	3	192.500	64.167	18.333	<0.001**
TxS	21	73.500	3.500		
CxT	3	2.563	0.854	1.805	0.177
CxTxS	21	4.750	0.226		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.40 ANOVA summary table for efficiency ranks in phase 3

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	52.563	52.563	9.961	0.016*
CxS	7	36.938	5.277		
T	3	129.125	43.042	9.527	<0.001**
TxS	21	94.875	4.518		
CxT	3	6.563	2.188	2.882	0.060
CxTxS	21	15.938	0.759		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.41 ANOVA summary table for efficiency ranks in phase 4

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	81.000	81.000	12.326	0.010*
CxS	7	16.000	6.571		
T	3	123.125	41.042	12.334	<0.001**
TxS	21	69.875	3.327		
CxT	3	0.875	0.292	0.405	0.751
CxTxS	21	9.938	0.473		
Total	63	336.000			

*p ≤ 0.01

Table A.17.42 ANOVA summary table for efficiency ranks in the overall tutoring process

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	81.000	81.000	12.326	0.010*
CxS	7	46.000	6.571		
T	3	115.875	38.625	10.123	<0.001*
TxS	21	80.125	3.816		
CxT	3	2.375	0.792	1.565	0.228
CxTxS	21	10.625	0.506		
Total	63	336.000			

*$p \leq 0.01$

Effectiveness

Table A.17.43 ANOVA summary table for effectiveness ranks in phase 1

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	27.563	27.563	4.831	0.064
CxS	7	39.938	5.705		
T	3	199.125	66.375	23.280	<0.001*
TxS	21	59.875	2.851		
CxT	3	1.313	0.438	1.122	0.363
CxTxS	21	8.188	0.390		
Total	63	336.002			

*$p < 0.01$

Table A.17.44 ANOVA summary table for effectiveness ranks in phase 2

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	42.250	42.250	6.326	0.040*
CxS	7	46.750	6.679		
T	3	149.375	49.792	11.798	<0.001**
TxS	21	88.625	4.220		
CxT	3	1.625	0.542	1.542	0.233
CxTxS	21	7.375	0.351		
Total	63	336.000			

*$p < 0.05$
**$p < 0.01$

Table A.17.45 ANOVA summary table for effectiveness ranks in phase 3

Source		df	SS	MS	F	p-value
Between						
	S	7	0.000	0.000		
Within						
	C	1	42.250	42.250	9.918	0.017*
	CxS	7	30.750	4.393		
	T	3	169.625	56.542	15.753	<0.001**
	TxS	21	75.375	3.589		
	CxT	3	6.875	2.292	4.326	0.016*
	CxTxS	21	15.500	0.738		
Total		63	340.375			

*p < 0.05
**p < 0.01

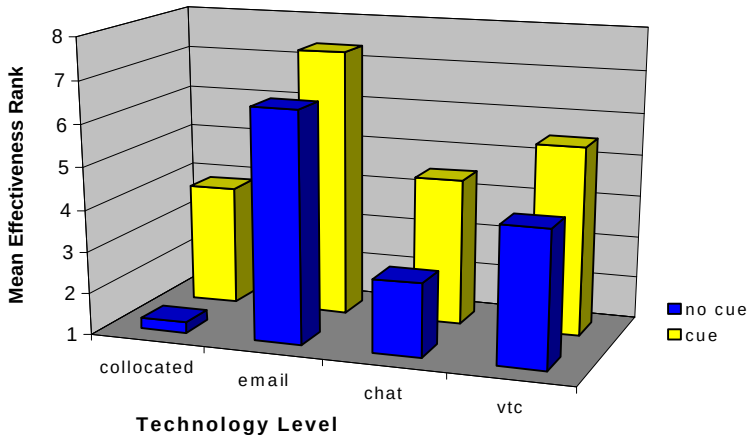


Figure A.17.22 Effectiveness ranked sums for the technology x feedback cue interaction in phase 3

Table A.17.46 Multiple comparisons of phase 3 effectiveness ranked sums for the technology x feedback cue interaction

	mean	Chatroom No Cue 2.750	Collocated Cue 3.875	VTC No Cue 4.250	Chatroom Cue 4.500	VTC Cue 5.500	Email No Cue 6.500	Email Cue 7.375
Collocated No Cue	1.250	1.500*	2.625*	3.000*	3.250*	4.250*	5.250*	6.125*
Chatroom No Cue	2.750		1.125	1.500*	1.750*	2.750*	3.750*	4.625*
Collocated Cue	3.875			0.375	1.125	1.625*	2.625*	3.500*
VTC No Cue	4.250				0.250	1.250	2.250*	3.125*
Chatroom Cue	4.500					1.000	2.000*	2.875*
VTC Cue	5.500						1.000	1.875*
Email No Cue	6.500							0.875

*p < 0.05

Table A.17.47 Descriptive statistics for phase 3 effectiveness ranks for the experimental conditions

		N	Mean	sd
Collocated	No Cue	8	1.250	0.707
	Cue	8	3.875	1.642
Email	No Cue	8	6.500	1.690
	Cue	8	7.375	0.744
Chatroom	No Cue	8	2.750	1.488
	Cue	8	4.500	1.414
Video	No Cue	8	4.250	1.669
Teleconferencing	Cue	8	5.500	1.773

Table A.17.48 ANOVA summary table for effectiveness ranks in phase 4

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	76.563	76.563	11.667	0.011*
CxS	7	45.938	6.563		
T	3	112.875	37.625	8.395	0.001**
TxS	21	94.125	4.482		
CxT	3	0.813	0.271	1.000	0.412
CxTxS	21	5.688	0.271		
Total	63	336.002			

*p < 0.05
**p < 0.01

Table A.17.49 ANOVA summary table for effectiveness ranks in the overall tutoring process

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	45.563	45.563	6.025	0.044*
CxS	7	52.938	7.563		
T	3	107.875	35.958	6.286	0.003**
TxS	21	120.125	5.720		
CxT	3	2.063	0.688	1.941	0.154
CxTxS	21	7.438	0.354		
Total	63	336.002			

*p < 0.05
**p < 0.01

Comfort

Table A.17.50 ANOVA summary table for comfort ranks in phase 1

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	36.000	36.000	4.582	0.070
CxS	7	55.000	7.857		
T	3	147.125	49.042	12.279	<0.001*
TxS	21	83.875	3.994		
CxT	3	1.875	0.625	1.082	0.378
CxTxS	21	12.125	0.577		
Total	63	336.000			

*p < 0.01

Table A.17.51 ANOVA summary table for comfort ranks in phase 2

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	42.250	42.250	4.868	0.063
CxS	7	60.750	8.679		
T	3	113.250	37.750	7.641	0.001*
TxS	21	103.750	4.941		
CxT	3	3.500	1.167	1.960	0.151
CxTxS	21	12.500	0.595		
Total	63	336.000			

*p < 0.01

Table A.17.52 ANOVA summary table for comfort ranks in phase 3

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	39.063	39.063	5.645	0.049*
CxS	7	48.438	6.920		
T	3	119.375	39.792	7.044	0.002**
TxS	21	118.625	5.649		
CxT	3	1.3125	0.438	1.000	0.412
CxTxS	21	9.188	0.438		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.53 ANOVA summary table for comfort ranks in phase 4

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	72.250	72.250	10.818	0.013*
CxS	7	46.750	6.679		
T	3	107.250	35.750	7.760	0.001**
TxS	21	96.750	4.607		
CxT	3	1.000	0.333	0.583	0.633
CxTxS	21	12.000	0.571		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.17.54 ANOVA summary table for comfort ranks in the overall tutoring process

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	72.250	72.250	10.818	0.013*
CxS	7	46.750	6.679		
T	3	115.250	38.417	8.989	0.001**
TxS	21	89.750	4.274		
CxT	3	2.000	0.667	1.400	0.271
CxTxS	21	10.000	0.476		
Total	63	336.000			

*p < 0.05
**p < 0.01

Appendix A.18 Satisfaction Ranks

Appendix A.18.1 Technology

Table A.18.1 Summary of Friedman's test results for technology satisfaction ranks

	df	S	p
Phase 2	3	11.48	0.010*
Phase 3	3	17.58	0.001**
Phase 4	3	17.00	0.001**
Overall	3	11.35	0.010*

*p < 0.05
**p < 0.01

Table A.18.2 Summary of the mean satisfaction rank and standard deviation for each technology level

		Collocated	Email	Chatroom	Video Teleconferencing
Phase 2	mean	1.625	3.563	2.000	2.812
	sd	1.061	0.496	0.535	1.067
Phase 3	mean	1.438	3.750	1.750	3.063
	sd	0.496	0.463	0.756	0.678
Phase 4	mean	1.312	3.687	1.938	3.063
	sd	0.458	0.458	0.776	0.776
Overall	mean	1.688	3.625	1.938	2.750
	sd	1.100	0.518	0.678	1.000

Phase 2:

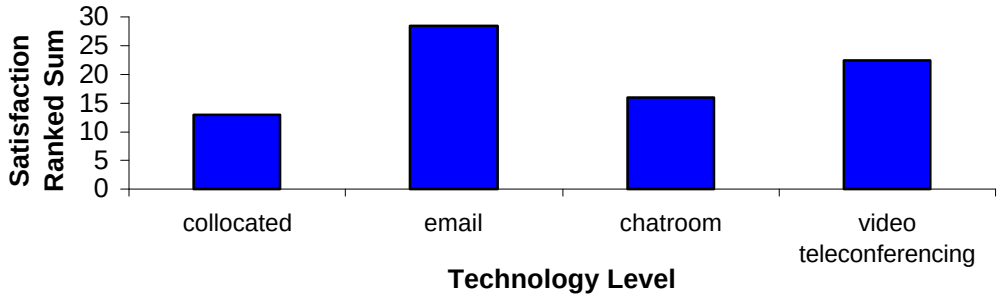


Figure A.18.1 Comparison of the satisfaction ranked sums for technology levels in phase 2

Table A.18.3 Multiple comparisons of satisfaction ranked sums for technology levels in phase 2

	ranked sum	Chatroom 16.0	Video Teleconferencing 22.5	Email 28.5
	ranked sum			
Collocated	13.0	3.0	9.5*	15.5**
Chatroom	16.0		6.5	12.5**
Video Teleconferencing	22.5			6.0

*p < 0.05
**p < 0.01

Phase 3:

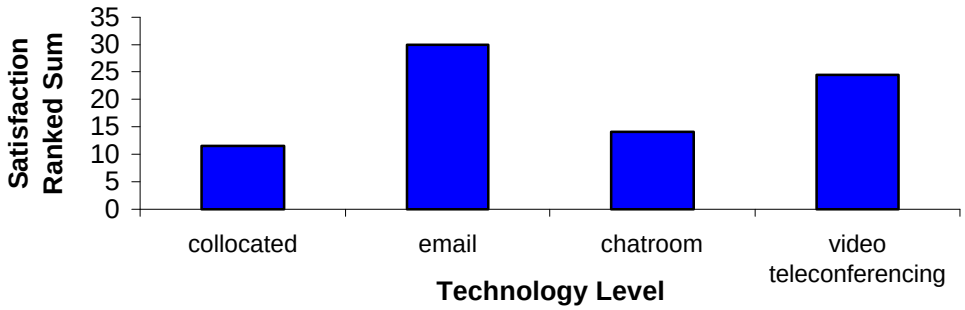


Figure A.18.2 Comparison of satisfaction ranked sums for technology levels in phase 3

Table A.18.4 Multiple comparisons of satisfaction ranked sums for technology levels in phase 3

		Chatroom	Video Teleconferencing	Email
	ranked sum	14.0	24.5	30.0
	ranked sum			
Collocated	11.5	2.5	13.0**	18.5**
Chatroom	14.0		10.5*	16.0**
Video Teleconferencing	24.5			5.5

*p < 0.05
**p < 0.01

Phase 4:

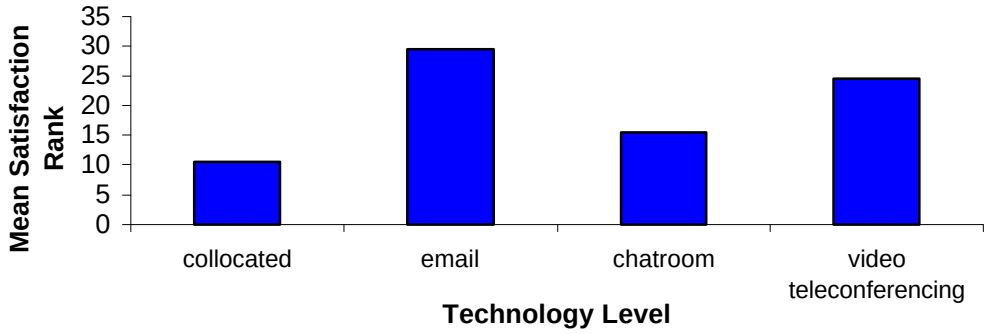


Figure A.18.3 Comparison of the satisfaction ranked sums for technology levels in phase 4

Table A.18.5 Multiple comparisons of satisfaction ranked sums for technology levels in phase 4

		Chatroom	Video Teleconferencing	Email
	ranked sum	15.5	24.5	29.5
	ranked sum			
Collocated	10.5	5.0	14.0*	19.0*
Chatroom	15.5		9.0	14.0*
Video Teleconferencing	24.5			5.0

*p < 0.01

Overall:

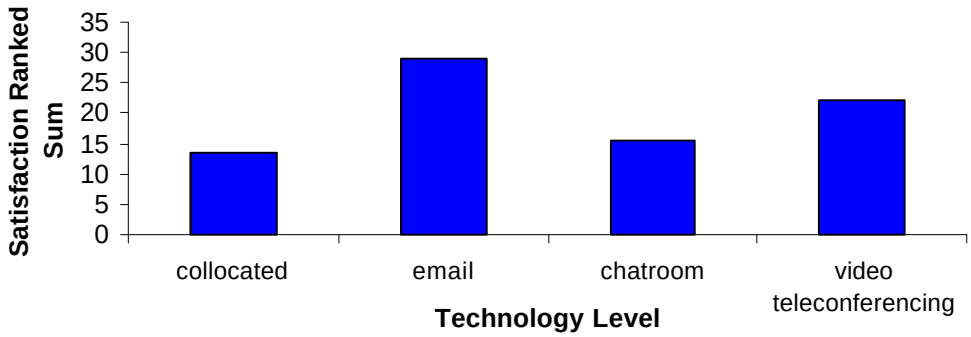


Figure A.18.4 Comparison of the overall satisfaction ranked sums for technology levels

Table A.18.6 Multiple comparisons of the overall satisfaction ranked sums for technology levels

		Chatroom	Video Teleconferencing	Email
	mean	15.5	22.0	29.0
	mean			
Collocated	13.5	2.0	8.5	15.5*
Chatroom	15.5		6.5	13.5*
Video Teleconferencing	22.0			7.0

*$p < 0.01$

Appendix A.18.2 Feedback Cue Satisfaction Ranks

Table A.18.7 Summary of Friedman's test results for feedback cue satisfaction ranks

	df	S	p
Phase 2	1	4.50	0.034*
Phase 3	1	4.50	0.034*
Phase 4	1	4.50	0.034*
Overall	1	3.57	0.059

*$p < 0.05$

Table A.18.8 Summary of the mean satisfaction rank and standard deviation for each feedback cue level

		Mean	Standard Deviation
Phase 2	No Cue	1.125	0.354
	Cue	1.875	0.354
Phase 3	No Cue	1.125	0.354
	Cue	1.875	0.354
Phase 4	No Cue	1.125	0.354
	Cue	1.875	0.354
Overall	No Cue	1.187	0.372
	Cue	1.813	0.372

Appendix A.18.3 ANOVA Tables for Satisfaction Ranks

Table A.18.9 ANOVA summary table for satisfaction ranks in phase 1

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	60.063	60.063	6.734	0.036*
CxS	7	62.438	8.920		
T	3	64.375	21.458	3.298	0.040*
TxS	21	136.625	6.506		
CxT	3	1.813	0.604	1.187	0.339
CxTxS	21	10.688	0.509		
Total	63	336.002			

*p < 0.05

Table A.18.10 ANOVA summary table for satisfaction ranks in phase 2

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	52.563	52.563	7.839	0.027*
CxS	7	46.938	6.705		
T	3	84.375	28.125	4.323	0.016*
TxS	21	136.625	6.506		
CxT	3	2.563	0.854	1.386	0.274
CxTxS	21	12.938	0.616		
Total	63	336.002			

*p < 0.05

Table A.18.11 ANOVA summary table for satisfaction ranks in phase 3

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	52.563	52.563	8.188	0.024*
CxS	7	44.938	6.420		
T	3	146.875	48.958	14.255	<0.001**
TxS	21	72.125	3.435		
CxT	3	1.313	0.438	0.505	0.683
CxTxS	21	18.188	0.866		
Total	63	336.002			

*p < 0.05
**p < 0.01

Table A.18.12 ANOVA summary table for satisfaction ranks in phase 4

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	64.000	64.000	8.145	0.025*
CxS	7	55.000	7.857		
T	3	122.375	40.792	10.625	0.000**
TxS	21	80.625	3.839		
CxT	3	2.125	0.708	1.253	0.316
CxTxS	21	11.875	0.566		
Total	63	336.000			

*p < 0.05
**p < 0.01

Table A.18.13 ANOVA summary table for satisfaction ranks in the overall tutoring process

Source	df	SS	MS	F	p-value
Between					
S	7	0.000	0.000		
Within					
C	1	33.063	33.063	4.029	0.085
CxS	7	57.438	8.205		
T	3	100.125	33.375	5.235	0.007*
TxS	21	133.875	6.375		
CxT	3	1.813	0.604	1.310	0.298
CxTxS	21	9.688	0.461		
Total	63	336.002			

*p < 0.01

Appendix A.19 MANOVA on Subjective Responses

Table A.19.1 MANOVA on subjects' perceptions of satisfaction, ease of use, efficiency, and effectiveness

Criterion	Test Statistic	F	df		p-value
Feedback Cue					
Wilk's	0.421	1.378	4	4	0.382
Lawley-Hotelling	1.378	1.378	4	4	0.382
Pillai's	0.579	1.378	4	4	0.382
Technology					
Wilk's	0.267	2.581	12	47	0.010*
Lawley-Hotelling	1.981	2.752	12	50	0.006*
Pillai's	0.943	2.292	12	60	0.018*
Phase					
Wilk's	0.543	1.036	12	47	0.434
Lawley-Hotelling	0.761	1.057	12	50	0.415
Pillai's	0.501	1.002	12	60	0.458
Feedback Cue x Technology					
Wilk's	0.467	1.330	12	47	0.234
Lawley-Hotelling	0.934	1.298	12	50	0.250
Pillai's	0.629	1.325	12	60	0.229
Feedback Cue x Phase					
Wilk's	0.610	0.821	12	47	0.628
Lawley-Hotelling	0.556	0.773	12	50	0.675
Pillai's	0.443	0.866	12	60	0.585
Technology x Phase					
Wilk's	0.627	0.834	36	226	0.737
Lawley-Hotelling	0.502	0.816	36	234	0.764
Pillai's	0.434	0.853	36	252	0.711
Feedback x Technology x Phase					
Wilk's	0.495	1.298	36	226	0.131
Lawley-Hotelling	0.790	1.283	36	234	0.141
Pillai's	0.629	1.307	36	252	0.123

*$p < 0.05$

Table A.19.2 MANOVA on subjects' overall perception of satisfaction, ease of use, efficiency, and effectiveness

Criterion	Test Statistic	F	df		p-value
Feedback Cue					
Wilk's	0.411	1.431	4	4	0.368
Lawley-Hotelling	1.431	1.431	4	4	0.368
Pillai's	0.589	1.431	4	4	0.368
Technology					
Wilk's	0.332	2.066	12	47	0.039*
Lawley-Hotelling	1.604	2.227	12	50	0.024*
Pillai's	0.812	1.857	12	60	0.059*
Feedback Cue x Technology					
Wilk's	0.580	0.913	12	47	0.541
Lawley-Hotelling	0.622	0.864	12	50	0.587
Pillai's	0.480	0.953	12	60	0.502

*$p < 0.05$

Appendix A.20 Correlation between Subjective Responses

Table A.20.1 Pearson product moment for satisfaction, ease of use, efficiency and effectiveness response

	Ease of Use	Efficiency	Effectiveness
Satisfaction	0.751	0.811	0.847
Ease of Use		0.826	0.818
Efficiency			0.853

Table A.20.2 Pearson product moment for overall satisfaction, ease of use, efficiency and effectiveness response

	Ease of Use	Efficiency	Effectiveness
Satisfaction	0.871	0.889	0.886
Ease of Use		0.882	0.895
Efficiency			0.898

Appendix A.21 Analysis of Ease of Use, Efficiency, and Effectiveness Responses

Ease of Use Response

Table A.21.1 ANOVA summary table for the ease of use response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	58.8086	8.4012		
Within					
P	3	0.418	0.139	0.468	0.707
PxS	21	6.238	0.297		
C	1	2.066	2.066	0.855	0.386
CxS	7	16.902	2.415		
T	3	43.199	14.400	5.849	0.005*
TxS	21	51.707	2.462		
PxC	3	0.824	0.275	1.136	0.358
PxCxS	21	5.082	0.242		
PxT	9	3.535	0.393	1.003	0.448
PxTxS	63	24.684	0.392		
CxT	3	7.856	2.619	1.581	0.224
CxTxS	21	34.801	1.657		
PxCxT	9	3.566	0.396	1.356	0.227
PxCxTxS	63	18.402	0.292		
Total	255	278.090			

* $p < 0.01$

Table A.21.2 ANOVA summary table for the overall ease of use response

Source	df	SS	MS	F	p-value
Between					
S	7	18.188	2.598		
Within					
C	1	0.063	0.063	0.119	0.741
CxS	7	3.687	0.527		
T	3	19.062	6.354	4.908	0.010*
TxS	21	27.187	1.295		
CxT	3	2.063	0.688	0.715	0.554
CxTxS	21	20.188	0.961		
Total	63	90.438			

*$p = 0.01$

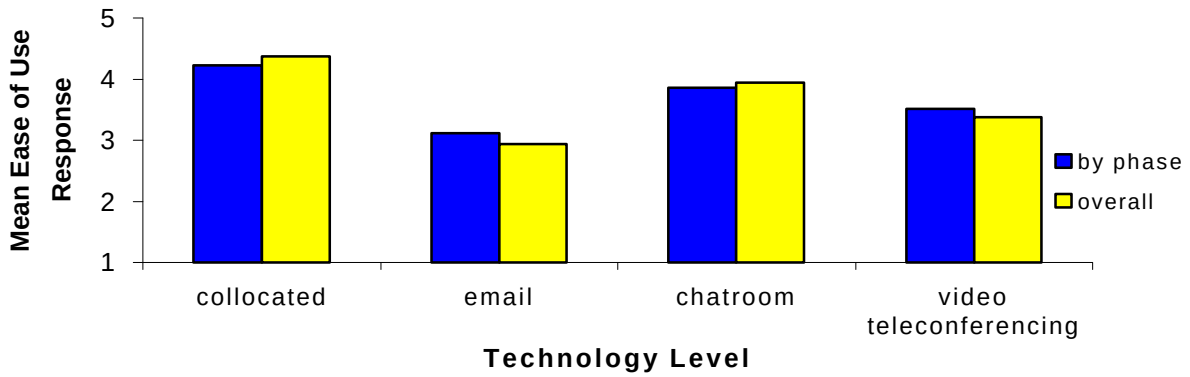


Figure A.21.1 Mean ease of use responses for technology levels

Table A.21.3 Multiple comparisons of the mean ease of use response for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.859	3.516	3.109
	mean				
Collocated	4.219		0.359*	0.703*	0.359*
Chatroom	3.859			0.344*	0.750*
Video Teleconferencing	3.516				0.406*

*p < 0.05

Table A.21.4 Multiple comparisons of the mean overall ease of use response for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.938	3.375	2.938
	mean				
Collocated	4.375		0.438	1.000*	1.438*
Chatroom	3.938			0.563	1.000*
Video Teleconferencing	3.375				0.438

*p < 0.05

Efficiency Response

Table A.21.5 ANOVA summary table for the efficiency response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	76.734	10.962		
Within					
P	3	1.172	0.391	0.893	0.462
PxS	21	9.203	0.438		
C	1	1.000	1.000	1.333	0.286
CxS	7	5.250	0.750		
T	3	47.266	15.755	7.585	0.001*
TxS	21	43.609	2.077		
PxC	3	0.313	0.104	0.220	0.881
PxCxS	21	9.938	0.473		
PxT	9	3.422	0.380	1.080	0.391
PxTxS	63	22.203	0.352		
CxT	3	7.531	2.510	1.029	0.400
CxTxS	21	51.219	2.439		
PxCxT	9	3.406	0.379	1.790	0.088
PxCxTxS	63	13.344	0.212		
Total	255	295.609			

* $p < 0.01$

Table A.21.6 ANOVA summary table for the overall efficiency response

Source	df	SS	MS	F	p-value
Between					
S	7	24.188	3.455		
Within					
C	1	0.000	0.000	0.000	1.000
CxS	7	8.25	1.179		
T	3	21.688	7.229	6.443	0.003*
TxS	21	23.563	1.122		
CxT	9	3.250	1.083	1.569	0.227
CxTxS	21	14.500	0.691		
Total	63	95.438			

*$p < 0.01$

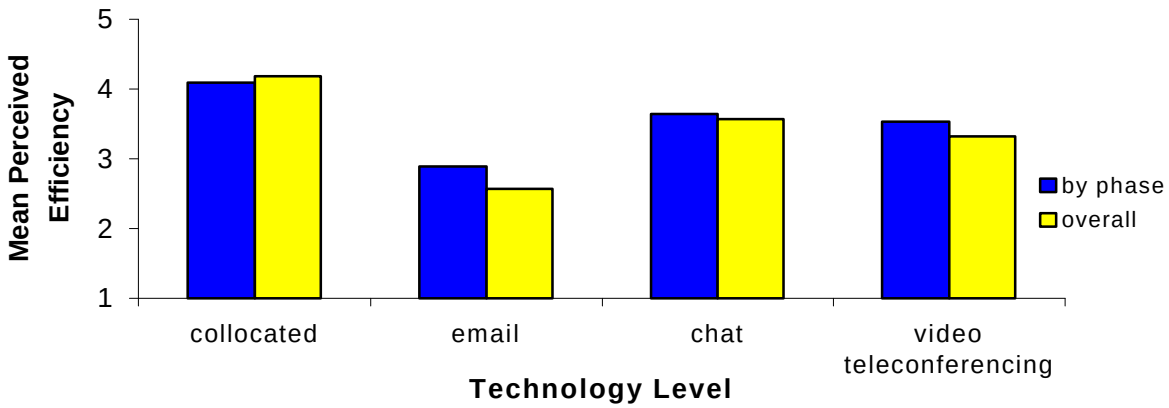


Figure A.21.2 Mean efficiency responses for each technology level

Table A.21.7 Multiple comparisons of the mean efficiency responses for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.563	3.312	2.563
	mean				
Collocated	4.187		0.453*	0.563*	1.203*
Chatroom	3.563			0.109	0.750*
Video Teleconferencing	3.312				0.641*

*p < 0.05

Table A.21.8 Multiple comparisons of the mean overall efficiency responses for technology levels

			Chatroom	Video Teleconferencing	Email
		mean	3.563	3.312	2.563
	mean				
Collocated	4.187		0.625*	0.875*	1.625*
Chatroom	3.563			0.250	1.000*
Video Teleconferencing	3.312				0.750*

*p < 0.05

Effectiveness Response

Table A.21.9 ANOVA summary table for effectiveness response in all phases

Source	df	SS	MS	F	p-value
Between					
S	7	79.777	11.397		
Within					
P	3	1.231	0.410	0.972	0.425
PxS	21	8.863	0.422		
C	1	0.004	0.004	0.005	0.949
CxS	7	6.152	0.879		
T	3	30.699	10.233	3.969	0.022*
TxS	21	54.145	2.578		
PxC	3	1.043	0.348	1.234	0.323
PxCxS	21	5.926	0.282		
PxT	9	4.004	0.445	1.435	0.193
PxTxS	63	19.527	0.310		
CxT	3	9.0112	3.004	1.651	0.208
CxTxS	21	38.207	1.819		
PxCxT	9	4.379	0.487	1.831	0.081
PxCxTxS	63	16.777	0.266		
Total	255	279.746			

* $p < 0.05$

Table A.21.10 ANOVA summary table for the mean overall effectiveness response

Source	df	SS	MS	F	p-value
Between					
S	7	21.871	3.124		
Within					
C	1	0.098	0.098	0.174	0.689
CxS	7	3.934	0.562		
T	3	16.543	5.514	4.577	0.013*
TxS	21	25.301	1.205		
CxT	3	2.481	0.827	1.717	0.194
CxTxS	21	10.113	0.482		
Total	63	80.340			

*$p < 0.05$

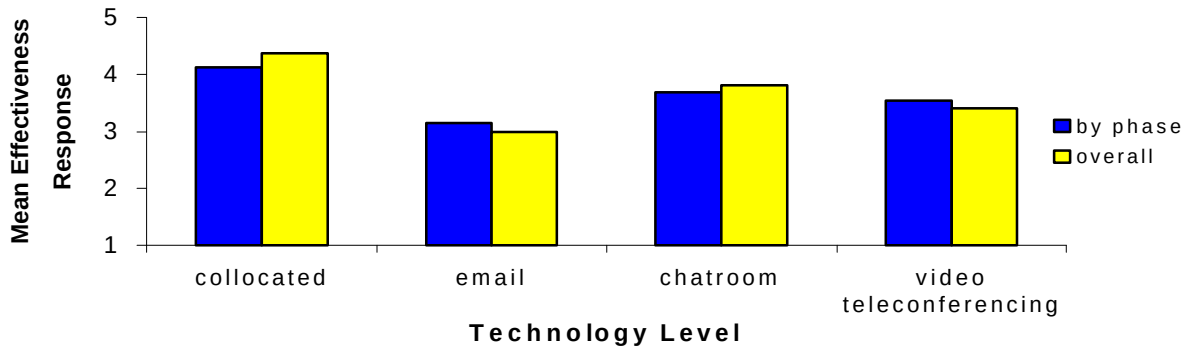


Figure A.21.3 Mean effectiveness responses for technology levels

Table A.21.11 Multiple comparisons of the mean effectiveness response for technology levels

		Chatroom	Video Teleconferencing	Email
	mean	3.688	3.547	3.156
	mean			
Collocated	4.125	0.437*	0.578*	0.969*
Chatroom	3.688		0.141	0.531*
Video Teleconferencing	3.547			0.391*

*p < 0.05

Table A.21.12 Multiple comparisons of the mean overall effectiveness response for technology levels

		Chatroom	Video Teleconferencing	Email
	mean	3.813	3.406	3.000
	mean			
Collocated	4.375	0.563*	0.969*	1.375*
Chatroom	3.813		0.406	0.813*
Video Teleconferencing	3.406			0.406

*p < 0.05

Appendix A.22 Tutor's Supplemental Ranks

Table A.22 Tutor's satisfaction, efficiency, ease of use, and effectiveness ranks

Phase	Feedback Cue Level	Technology Level	Satisfaction	Efficiency	Ease of Use	Effectiveness
1	no cue	collocated	1	1	1	1
1	no cue	email	8	8	8	8
1	no cue	chatroom	6	5	3	6
1	no cue	video teleconferencing	4	3	2	4
1	cue	collocated	2	2	4	2
1	cue	email	7	7	7	7
1	cue	chatroom	5	6	6	5
1	cue	video teleconferencing	3	4	5	3
2	no cue	collocated	1	1	1	1
2	no cue	email	8	8	8	8
2	no cue	chatroom	6	6	6	4
2	no cue	video teleconferencing	4	4	4	3
2	cue	collocated	2	2	2	2
2	cue	email	7	7	7	7
2	cue	chatroom	5	5	5	6
2	cue	video teleconferencing	3	3	3	5
3	no cue	collocated	1	1	1	1
3	no cue	email	8	8	8	8
3	no cue	chatroom	6	6	6	6
3	no cue	video teleconferencing	5	4	4	4
3	cue	collocated	2	2	2	2
3	cue	email	7	7	7	7
3	cue	chatroom	4	5	5	5
3	cue	video teleconferencing	3	3	3	3
4	no cue	collocated	1	1	1	1
4	no cue	email	8	8	8	8
4	no cue	chatroom	6	6	6	6
4	no cue	video teleconferencing	4	4	4	5
4	cue	collocated	2	2	2	2
4	cue	email	7	7	7	7
4	cue	chatroom	5	5	5	4
4	cue	video teleconferencing	3	3	3	3
overall	no cue	collocated	1	1	1	1
overall	no cue	email	8	8	8	8
overall	no cue	chatroom	6	6	6	6
overall	no cue	video teleconferencing	4	4	4	4
overall	cue	collocated	2	2	2	2
overall	cue	email	7	7	7	7
overall	cue	chatroom	5	5	5	5
overall	cue	video teleconferencing	3	3	3	3

Appendix A.23 Ranked Sums for Tutor's Perceptions

Table A.23.1 Tutor's ranked sums for technology's ease of use

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
Collocated	5	3	3	3	3
Email	15	15	15	15	15
Chatroom	9	11	11	11	11
Video Teleconferencing	7	7	7	7	7

Table A.23.2 Tutor's ranked sums for technology's efficiency

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
Collocated	3	3	3	3	3
Email	15	15	15	15	15
Chatroom	11	11	11	11	11
Video Teleconferencing	7	7	7	7	7

Table A.23.3 Tutor's ranked sums for technology's effectiveness

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
Collocated	3	3	3	3	3
Email	15	15	15	15	15
Chatroom	11	10	11	10	11
Video Teleconferencing	7	8	7	8	7

Table A.23.4 Tutor's ranked sums for feedback cue's ease of use

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
No Cue	14	19	19	19	19
Cue	21	17	17	17	17

Table A.23.5 Tutor's ranked sums for feedback cue's efficiency

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
No Cue	17	19	19	19	19
Cue	19	17	17	17	17

Table A.23.6 Tutor's ranked sums for feedback cue's effectiveness

Technology Level	Phase 1 Ranked Sum	Phase 2 Ranked Sum	Phase 3 Ranked Sum	Phase 4 Ranked Sum	Overall Ranked Sum
No Cue	19	16	19	20	19
Cue	17	20	17	16	17

Appendix A.24 MANOVA on Tutor's Subjective Responses

Table A.24 MANOVA on tutor's perceived satisfaction, ease of use, efficiency, and effectiveness response

Criterion	Test Statistic	F	df		p-value
Feedback Cue					
Wilk's	0.647	0.547	4	4	0.714
Lawley-Hotelling	0.547	0.547	4	4	0.714
Wilk's	0.353	0.547	4	4	0.714
Technology					
Wilk's	0.029	11.297	12	47	<0.001*
Lawley-Hotelling	18.593	25.824	12	50	<0.001*
Wilk's	1.451	4.686	12	60	<0.001*
Feedback Cue x Technology					
Wilk's	0.516	1.136	12	47	0.356
Lawley-Hotelling	0.783	1.088	12	50	0.390
Wilk's	0.567	1.165	12	60	0.329

*$p < 0.05$

Appendix A.25 Analysis of the Tutor's Ease of Use, Efficiency, and Effectiveness Response

Ease of Use Response

Table A.25.1 ANOVA summary table for the tutor's ease of use response

Source	df	SS	MS	F	p-value
Between					
S	7	7.109	0.790		
Within					
C	1	0.016	0.016	0.068	0.802
CxS	7	1.609	0.230		
T	3	64.547	21.516	118.029	<0.001*
TxS	21	3.828	0.182		
CxT	3	0.297	0.099	0.217	0.884
CxTxS	21	9.578	0.456		
Total	63	86.984			

*p < 0.001

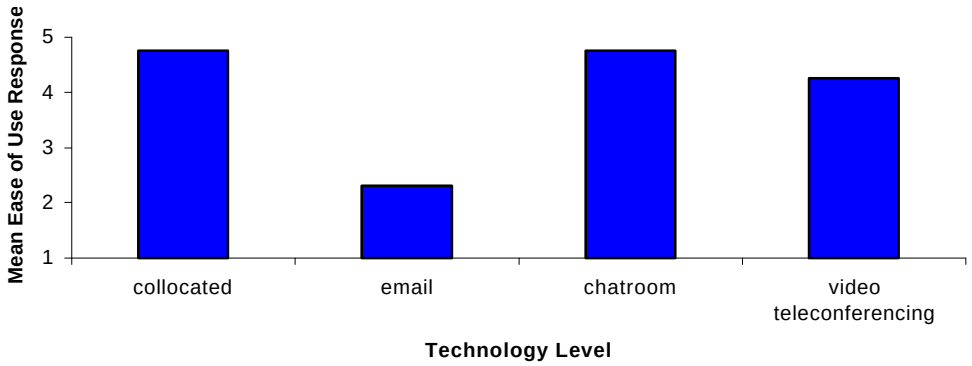


Figure A.25.1 Comparison of the tutor's mean ease of use response for technology

Table A.25.2 Multiple comparisons of the tutor's mean ease of use responses for technology levels

		Chatroom	Video Teleconferencing	Email
	mean	4.750	4.250	2.313
	mean			
Collocated	4.750	0.000	0.500*	2.437*
Chatroom	4.750		0.500*	2.437*
Video Teleconferencing	4.250			0.500*

*p < 0.05

Efficiency Response

Table A.25.3 ANOVA summary table for the tutor's efficiency response

Source	df	SS	MS	F	p-value
Between					
S	7	3.984	0.569		
Within					
C	1	0.391	0.391	0.522	0.493
CxS	7	5.234	0.748		
T	3	78.422	26.141	52.516	<0.001*
TxS	21	10.453	0.498		
CxT	3	0.672	0.224	0.511	0.679
CxTxS	21	9.203	0.438		
Total	63	108.359			

*p < 0.05

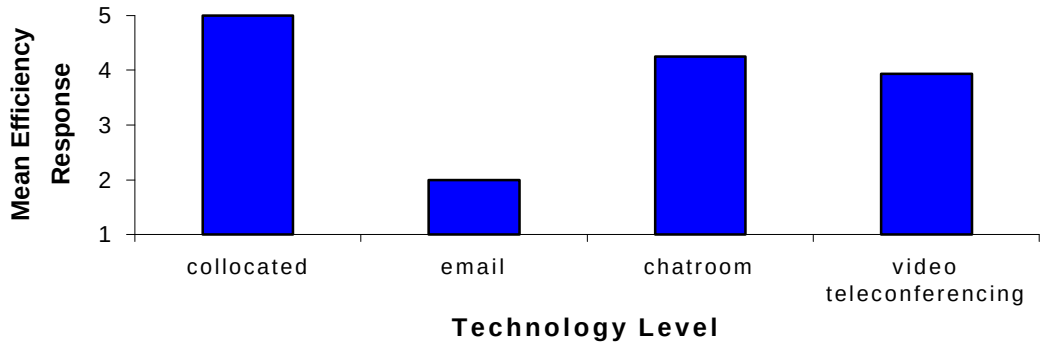


Figure A.25.2 Comparison of the tutor's mean efficiency response for technology

Table A.25.4 Multiple comparisons of the tutor's mean efficiency response for technology levels

			Chatroom	Video Teleconferencing	Email
	mean	mean	4.250	3.938	2.000
Collocated	5.000		0.750*	1.062*	3.000*
Chatroom	4.250			0.312	2.250*
Video Teleconferencing	3.938				1.938*

*p < 0.05

Effectiveness Response

Table A.25.5 ANOVA summary table for tutor's effectiveness response

Source	df	SS	MS	F	p-value
Between					
S	7	6.187	0.884		
Within					
C	1	0.063	0.063	0.137	0.722
CxS	7	3.187	0.455		
T	3	60.188	20.063	41.870	<0.001*
TxS	21	10.062	0.479		
CxT	3	1.188	0.396	0.869	0.473
CxTxS	21	9.563	0.455		
Total	63	90.438			

*p < 0.001

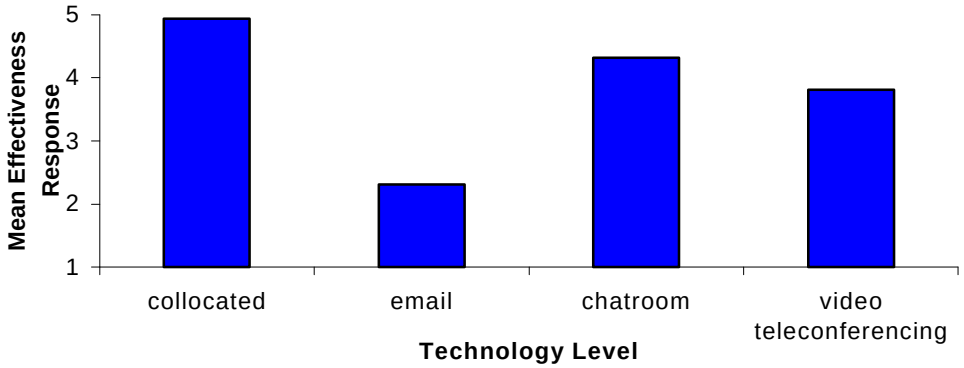


Figure A.25.3 Comparison of the tutor's mean effectiveness response for technology

Table A.25.6 Multiple comparisons of the tutor's mean effectiveness response for technology levels

			Chatroom	Video Teleconferencing	Email
	mean	mean	4.313	3.813	2.313
Collocated	4.938		0.625*	1.125*	2.625*
Chatroom	4.313			0.500*	2.000*
Video Teleconferencing	3.813				1.500*

*p < 0.05

Appendix A.26 ANOVA Summary Tables for Process Effects

Accuracy

Table A.26.1 ANOVA summary table for accuracy in phase 1

Source	df	SS	MS	F	p-value
O	7	84.437	12.063	1.412	0.226
S	7	25.438	3.634	0.425	0.881
T	7	77.688	11.098	1.299	0.275
R	42	358.875	8.545		
Total	63	546.438			

Table A.26.2 ANOVA summary table for accuracy in phase 2

Source	df	SS	MS	F	p-value
O	7	50.109	7.158	1.573	0.170
S	7	38.859	5.551	1.220	0.314
T	7	41.609	5.944	1.306	0.271
R	42	191.156	4.551		
Total	63	321.733			

Table A.26.3 ANOVA summary table for accuracy in phase 4 (excluding incomplete data)

Source	df	SS	MS	F	p-value
O	7	22.099	3.157	1.430	0.226
S	7	7.022	1.003	0.454	0.860
T	7	28.764	4.109	1.861	0.107
R	34	75.085	2.208		
Total	55	132.97			

Table A.26.4 ANOVA summary table for the overall accuracy (excluding incomplete data)

Source	df	SS	MS	F	p-value
O	7	397.442	56.777	1.473	0.211
S	7	496.499	70.928	1.840	0.112
T	7	389.843	55.692	1.445	0.221
R	33	1271.995	38.545		
Total	54	2555.779			

Process Time

Table A.26.5 Phase 3 ANOVA summary table for order effects between expected and observed process times

Source	df	SS	MS	F	p-value
O	7	364.757	52.108	2.151	0.060
S	7	223.613	31.945	1.319	0.267
T	7	303.553	43.365	1.790	0.116
R	40	968.853	24.221		
Total	61	1860.776			

Table A.26.6 ANOVA summary table for time to complete phase 4

Source	df	SS	MS	F	p-value
O	7	556.781	80.969	1.333	0.265
S	7	372.181	53.169	0.875	0.536
T	7	940.952	134.422	2.213	0.058
R	34	2065.380	60.746		
Total	55	3935.294			

Appendix A.27 Subjects' Written Opinions from Questionnaires

Table A.27 Subjects' opinions from the supplemental questionnaires

Condition	Task	Communication	Tutoring Process	Feedback Cue
collocated	1	I am not sure if it was most effective but I did understand the problem and how to work it and did solve it	good process but can get confusing going back. But good idea to see where you went wrong and what steps you missed where.	
Collocated	2	I like this method personally	It has to grow on me. I'll like it more once I've used it more	
collocated	3	Its very direct and personal. It allows for subtle clues ie. Body gestures to communicate my level of understanding.	I think it is extremely effective. It allows you to think through the problem and solve it for yourself. Otherwise you are simply copying off of someone else and never learn the concept behind the process.	
Collocated	4	This method is fast and has no problems	This problem is effective in that the tutor is able to see your diagrams and give feedback	
collocated	5	I like it. A bit to quite though. I like for someone to correct me if they see an initial mistake that proves the rest of my work wrong, wrong, wrong, wrong! ☹	Great ☺ ! It helps me visulize what I am doing, why I am doing it, and what I have to do – and leave out what I don't need to do.	
Collocated	6	It only took a half hour to finish this problem	It helps a student put concepts to use instead of just getting by on plugging in #'s into an equation.	
Collocated	7	It is easy and takes little time	Problem solving makes you use what you already know	
collocated	8	I like this method because the tutor can see exactly what you are doing & can immediately answer any questions I may have. The only thing I don't like about face-to-face is that it is hard to concentrate on the problem when someone is staring down your throat	The problem solving process works is you are able to develop the right plan to follow.	
Collocated cue	1	If you can see the tutor face-to-face you can sometimes tell if you are on the right track to solving the problem by the tutor's facial expressions.	The problem solving process is too long if you know what you're doing.	Since I understood the problem once I began working it I didn't feel I needed to turn on the low level of understanding. I don't really think it helped the tutor understand my level of understanding better
collocated cue	2	It was very easy and I felt I understood more	using problem solving is good because you have to apply what you know	I helped in communicating with the tutor

Table A.27 Subjects' opinions from the supplemental questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
collocated cue	3	It's ok without the feedback cue. But because I never say something is wrong it works for someone like me	I still hat problem solving but it forces one to learn the work.	It was a pain
collocated cue	4	I like it. Face to face is not always possible but it lets the tutor get a feel for what you are thinking. It also make's one think harder and review the work done knowing somebody's watching you.	It was great! There are many factors to be aware of while solving many step solutions. Those shapes were complied of numerous shapes that had to be accounted for in order to get an accurate surface area. I almost forgot 2 of the shapes myself! I like how I can refer to equations in previous steps to review and possible alter. The steps let me look at what I know vs. what I need to know!	It was ok. I really didn't use it much because when I work a problem my attention is shifted to one area. I believe if the cues were closer to me or in my face it would be a better learning tool.
collocated cue	5	It is just a replacement of verbal communication	I can let my tutor know whether I understand the problem or not.	The feedback cue is more of distraction from the problem
collocated cue	6	It is good	It is good, refer to prior discussion.	It was pointless, irritating, and time consuming, since I am sitting face to face.
collocated cue	7	It's normal	It's positive	It wasn't very helpful, I forgot it was there.
collocated cue	8	One on one is much easier interaction than just e-mail, chat room, audio-video, etc. because it is easier for the tutor to understand what you are thinking if they can see your reasoning on paper. Also time is not wasted as much trying to get each other to visualize what you are really talking about you can just point to it on the page.	I like the problem solving method. It helps you know how logical you are thinking before the problem is attempted to be worked.	The feedback que is a positive & helpful idea as long as you remember to use it but sometimes you are not sure as to how much you really understand b/c you may understand one part that you didn't before but the answer to your first problem creates a problem.
email	1	Its not for me. Its cool but I'd rather a face to face tutor.	Its a good process. Try it with more people they will like it.	
email	2		The e-mail is so slow, and messages overlap so that the tutor will ask me a question twice when I have already sent the message. This took a lot of time since I have to cheque for e-mail!	
email	3	less effective than one on one tutoring because visual help can help with minor problems	effective	
email	4	too slow hard for communication	this problem was a pain	
email	5	It is very tedious, and time consuming	It is a little time consuming, but overall worth the time in the long run learning process for long term memory retention.	

Table A.27 Subjects' opinions from the supplemental questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
email	6	The process took so much longer because I had to think of words to explain things that a drawing would have clearly expressed. It also took the tutor longer to respond because email wasn't exactly made for drawing.	I think I really went through the steps today and I asked more questions than usual. That may be the reason I actually got one right without having to go back and correct.	
email	7	Great. It gives you the opportunity to look over what the tutor said without losing your focus or asking him to repeat himself. That is where this has an advantage over video conf. However video. conf. I believe is quicker therefore saving me time. There is less typing (vid. conf.) and more attn. focused. Vid. conf. also has the option of typing steps and viewing the person and hearing them speak. Its Mega!	Great. A little slow sometimes but that just allows me to look over what I done and understand it more. Helps eliminate the risk of small mistakes, and huge errors. FABULOUS.	
email	8	It's easy but takes a lot of time	Problem solving is a good tutoring method	
email cue	1	The communication method took up a lot of time	I liked the problem solving process	I don't think it was very useful
email cue	2	Great, Quick, anytime, or place!	Good, although I think it could use a little more precision in the steps. I believe the key is short visual examples.	It was O.K. Not that great but there. Useful
email cue	3	I don't like it because I don't type well.	I think it works, but it is long.	I didn't really feel like I used it.
email cue	4	It is tedious and time consuming. It doesn't allow for clear communication	It was very effective	It was very helpful during the down time between email messages
email cue	5	email is a pain -- too slow	In this problem - yuck - I know how to do problems like this normally, but not w/ functions and as a cylinder & cone -- only with triangles and rectangles.	w/ email it helps, but not enough for me to like email any better
email cue	6	The delay in getting messages can be a little frustrating	The problem solving process help you think on your own as long as all of your thoughts are logically correct.	The feedback cue is a great help
email cue	7		The email is useful for multiple tutoring	It is more of a distraction
email cue	8	takes a while	It helps	I tend to forget that its there

Table A.27 Subjects' opinions from the supplemental questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
chatroom	1	The chat process is a good idea for tutoring multiple students that would no have access to a tutor. I would benefit from having an actual tutor since 1. he can talk to me, which is faster than typing, 2. the tutor can not draw diagrams to explain the math problem. Although an actual tutor would be better than chat, the chat tutor is very helpful in the math solving process. Chat is also very monotonous.		
chatroom	2	It's ok -, but I had to adjust to the fact that the computer is not really made to type math equations	Still hate problem solving, but it probably took less time that it would have own my own.	
chatroom	3	Its better than email	Use it. I like it.	
chatroom	4	I like that I was basically able to just go through the problem on my own. It didn't seem like the usual long hour.	I think the process works to help organize thoughts. I never really had as much success using it until today when I really concentrated on using it.	
chatroom	5	I like the light better when used along with the chat-room	The problem solving is a good process unless you get confused then old paper and pencil (visuals) are handy to let the tutor know what you are really thinking so they will know where your thought process went wrong.	
chatroom	6	It is easy to use and understand	Problem solving makes you apply what you already know	
chatroom	7	Its ok a little time consuming but beneficial	It was grrrreat.	
chatroom	8	Great. Sometimes confusing, in that I can sometimes be caught up in my work and realize the tutor has asked me 2 or 3 questions. But it's ok.	Good. Gives plenty of time to review and make sure all info is correct before advancing to next step.	
chatroom cue	1	I think it is a fast and easy method of getting help. Do you have this in any other subjects.	It was good. And it helped see where someone could have gone wrong.	I really didn't like it to much and I forgot it was there. Sometimes, if you could develop a system so that you could look at the screen and click on your level of understanding. I think that would be better - but I still think it's cool
chatroom cue	2	very effective because it eliminates time consuming and non-germane details. It also illiminated intimidation and personality conflicts.	very effective because it doesn't blindly lead you through steps. It almost forces you to understand the concept behind the math.	moderately effective became a little cumbersome during the problem solving process

Table A.27 Subjects' opinions from the supplemental questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
chatroom cue	3	I felt more comfortable	it is effective	It was useful
chatroom cue	4	it is ok	The problem solving process is good to help the student come up with their own solutions & methods but when you get stuck it is murder if you don't catch on.	The feedback que is great!
chatroom cue	5	I don't particularly like chat because I feel like I'm under pressure to answer faster	It helps keep my ideas organized.	I don't usually pay attention to the feedback cue
chatroom cue	6	Its good but threes too many for chat	its cool.	Its helpful
chatroom cue	7	The chatroom slows you down because you have to keep scrolling back to see if the tutor is talking to you and you're always checking the screen.	Still don't like it.	I didn't really use it this time
chatroom cue	8	It is fast and instant	The chat is good with out the cue.	It is just a distraction
video teleconferencing	1	it's easier on both people's time - when meeting the 2 people can be in diff. locations and get it done without worrying about time too much	I dislike problem solving in the first place, but once I got started it was simple.	
video teleconferencing	2	I don't like it. It was hard to hear and understand the tutor and it was hard for the tutor to see what part I didn't understand.	I think the problem solving process works better face-to-face than by video teleconferencing.	
video teleconferencing	3	This method is to slow for tutoring	The sound is not clear but the video is useful for diagram representation for problems. The chat is useful in care of failure of the sound.	
video teleconferencing	4	It was hard to understand the tutor	Problem solving is a good process because you have to apply what you already know.	
video teleconferencing	5	its cool. good to use	its helpful	
video teleconferencing	6	Great! Easy to use but the audio needs a little more clarification. It is interesting, fun, and is easy to use if you were at home and felt lazy (me) :)	Good, gives a personal effect in that you control the process of solving the problem. You write what you know, put it in your own words, and basically gear the problem to your own standards. There is always room for more than one method of solving things. Assistance is there when needed so that you do not stray to far off from the right solution :)	
video teleconferencing	7	The video delay makes it very hard to watch the screen and listen at the same time. & the voice does not come through very clearly.	Great process.	
video teleconferencing	8	It is very effective but the voice was very raspy and the camera timing was slow.	Its fannnntastic.	

Table A.27 Subjects' opinions from the supplemental questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
video teleconferencing cue	1	I think it has a lot of potential. It still needs a little higher resolution on the picture screen, and the speakers need to be a little clearer.	I think it is extremely useful. It allows the student to think through it an figure it out for themselves. I felt like I was learning the problem instead of just copying someone elses techniques.	It was a little tedious at first, because it was distracting. It became increasingly useful when I had problems.
video teleconferencing cue	2	It is a little choppy and the screen and voice sometimes threw me off when the transmission was cloudy	It is good but sometime I can't logically pull the correct strings but the logic map helps me see where I got confused or stoped before I reached a correct answer.	The feedback is a great idea instead of trying to explain confusion
video teleconferencing cue	3	I like it. It gives a sense of personalization. Makes one want to do better because they are being watched.	Good. Please stress the importance of a good beginning and what to look for. Never be fooled by a diagram! After that other things fall in place.	it was o.k.
video teleconferencing cue	4	Its better than the rest	its good I guess	It could have been more clear, but other than a couple of miscues it was good.
video teleconferencing cue	5	It is hard to understand what the tutor is saying	Problem solving is a good method	It doesn't really tell the tutor what you understand
video teleconferencing cue	6	The feedback cue is of no use since I can use the video conferencing for feedback		The video conferencing is slow and hard to understand
video teleconferencing cue	7	I think this method works well when the volume is properly adjusted. I had difficulties last time because it wasn't.	The problem solving process was good for this problem because the method of finding inverses has specific steps to follow.	I realized that when the feedback cue is being used, the tutor is not constantly asking "how is it going" and I don't have to keep stopping to say I'm doing fine.
video teleconferencing cue	8	Well, the tutor can see most of what you are doing. If you're frustrated w/ the problem - he or she can tell.	I dislike these types of problems no matter what - putting them in this form makes no difference.	I didn't use it, but once -- sort of pointless

Appendix A.28 Subjects' Opinions after Participating in All Trials

Table A.28 Subjects' opinions after participating in all experimental conditions

Subject	Condition	Comment
1	collocated	(+) Obviously great, 1-on-1 personal direct advice given in an instant. Face to face also provides for a set of eyes letting you know if you did something wrong before you do it further. (-) Sometimes privacy can help settle you and helps you think better. Takes time to go see a tutor in real life. (For example working in front of a professor can be stressful if you're not sure.
2	collocated	I liked the personal attention. Also there was a much better sense of communication ie. Body language.
3	collocated	The best condition because it allows visual & clear audio; and it allows the tutor to better follow the student's logic by seeing his/her work.
4	collocated	Its easy you see what he's talking about and he sees what your talking about and it saves time
5	collocated	The most effective, fast, no interruption.
6	collocated	Easier – the tutor can see exactly what and how you're doing – communications not limited by a machine
7	collocated	I think this one is the best because your tutor can save you time by telling you what you are doing wrong before you get too lost on the wrong path. The tutor can see any diagrams & equations you write. You don't have to worry about trying to draw on the computer or explain something in writing that is easily expressed with pictures.
8	collocated	Easy and quick method for tutoring
1	collocated cue	(+) Has positive characteristics of above [face to face] but also informs tutor on you level of understanding. (-) Same as above although I really never paid to much attention to it. It didn't really work for me but it's a great idea and let's tutor know where you are.
2	collocated cue	This was very similar to my face to face session with the exception that the feedback cue was tedious and unnecessary.
3	collocated cue	The feedback cue is very helpful especially when you know that you have done something wrong but cannot quite figure it out.
4	collocated cue	The feedback cue isn't needed for face to face.
5	collocated cue	The feedback cue slowed down the tutoring process. This comment goes for all methods with tutoring. It is just a second communication device.
6	collocated cue	Same as the 1st in some respects but sometimes one forgets to use the cues
7	collocated cue	I think it is just as good as face to face but I never really paid attention to the feedback cue. I just turned it on high level and let it stay there while I focused on the problem.
8	collocated cue	feedback cue is not needed when working face to face
1	email	(+) Puts info in nice little unconfusing packages. (-) Takes way to LONG. You have to check sometimes too! Easier to mess up and close the wrong thing.
2	email	Was the worst of all tutoring tools. It was slow **impersonal and overall extremely tedious.**
3	email	Very annoying waiting for the mail to send & be answered. Every misunderstanding has to be explained through words which consumes time.
4	email	It wastes time waiting for it to come through, you get impatient.
5	email	Good, But you have to check messages frequently, otherwise, they overlap.

Table A.28 Subjects' opinions after participating in all experimental conditions (continued)

Subject	Condition	Comment
6	email	too slow
7	email	This could be good if it was faster. I personally didn't like it because I had to wait 5 years for an answer & then when I needed to respond, I had to type (which I do very slowly) and try to explain pictures in words. I think this takes away from the focus on the problem
8	email	It takes a lot of time to relay a message
1	email cue	(+) Same as above [email + comment]. (-) Same as above [email] but for me constantly stopping what I'm doing to think of how I'm doing disrupts my flow.
2	email cue	Same [as with email] w/ the Exception that the feedback cue was ten times more tedious.
3	email cue	The feedback cue helps the e-mail condition alot better by letting the tutor know if relayed questions and answers are comprehended.
4	email cue	Again the cue to me is not necessary
5	email cue	The feedback cue slowed down the tutoring process. This comment goes for all methods with tutoring. It is just a second communication device.
6	email cue	Even slower
7	email cue	Same as above [email]. I don't think the cue did anything except let me mostly work the problem on my own.
8	email cue	It helps because the tutor cannot see you.
1	chatroom	(+) My favorite. Very fast, user friendly. You can be at home in a relaxing atmosphere and just hook up whenever. You can scroll up and down on previous messages too! (-) When more people get on there is more confusion!
2	chatroom	It was extremely helpful. It allowed you to see the problem from several perspectives and learn faster.
3	chatroom	The chat is more efficient than e-mail because it allows almost immediate response (you don't have to keep checking you mail) things flow alot faster also
4	chatroom	It helps because you have three people you communicate with so if you don't understand one's answer you can get it from another person. You might understand it better from that person.
5	chatroom	The second best next to face to face
6	chatroom	Slow, but because you have other students working w/ you makes things easier
7	chatroom	I was able to work the problem a little ahead sometimes because there were two other people occupying the tutor's attention. As long as I understand the problem this didn't bother me because I like to work at my own pace.
8	chatroom	Easy quick and effective because everyone is stating there ideas
1	chatroom cue	(+) Same as above [+ chat]. (-) Composition of (-) feedback cue for first two [collocated & email] Sometimes I get caught up in work and miss things but it gives me the opportunity to scroll up and see what's going on.
2	chatroom cue	This was especially helpful since the tutor was divided between multiple students.
3	chatroom cue	The feedback cue further improves the chat communication. Just as e-mail doesn't always clearly translate the cues help the tutor know if their explanation was helpful enough.
4	chatroom cue	Its confusing unless only one person has it.

Table A.28 Subjects' opinions after participating in all experimental conditions (continued)

Subject	Condition	Comment
5	chatroom cue	The feedback cue slowed down the tutoring process. This comment goes for all methods with tutoring. It is just a second communication device.
6	chatroom cue	Same - feedbacks are still a waste
7	chatroom cue	Same as above. I suppose the cue helped the tutor by being able to see who had a good understanding and who didn't.
8	chatroom cue	It helps because there is more than one student
1	video teleconferencing	(+) 2nd to face-to-face more convient in that you can be at home. Fascinating! Gives opportunity for chat as well. (-) AUDIO! If that was fixed this would definitely be #1 (give it a few years (crossed out years) months)+
2	video teleconferencing	This was good but a little difficult due to the technology being slow and the verbal communication being a little unclear.
3	video teleconferencing	Video teleconferencing would be alot better if the graphics and audio system were clear. If the video/camera focused on the paper instead of the person's face I believe it would be more effective.
4	video teleconferencing	Its cool because I haven't used it before but the voices make you waste time because they sometimes aren't clear.
5	video teleconferencing	Slow and hard to use for communicate.
6	video teleconferencing	Slow - you can't always understand one another I can't let out frustration by making faces if the tutor can see me.
7	video teleconferencing	This one worked really well when the volume was adjusted. You could verbally communicate rather than type on the computer. I think it is a pretty good second to face to face communication.
8	video teleconferencing	Not easy and not effective because it is too hard to understand the tutor
1	video teleconferencing cue	(+) Same as above [vtc] (-) Feedback cue problems of above!
2	video teleconferencing cue	Same [as in VTC] except it was a helpful tool when communication was bad.
3	video teleconferencing cue	The cues also help the video audio telecon. but not as much as it does for the chat/e-mail because the tutor can see the student being hesitant or facial expressions.
4	video teleconferencing cue	Like I said before you forget that its there because your fascinated over whats on the screen.
5	video teleconferencing cue	The feedback cue slowed down the tutoring process. This comment goes for all methods with tutoring. It is just a second communication device.
6	video teleconferencing cue	Same - I didn't use me feedback for more than the 1st phase of my session.
7	video teleconferencing cue	This one worked really well when the volume was adjusted. You could verbally communicate rather than type on the computer. I think it is a pretty good second to face to face communication.
8	video teleconferencing cue	Useful since it is hard to understand the tutor

Appendix A.29 Tutor's Opinions from Questionnaires and after Completing All Trials

Table A.29.1 Tutor's opinions from questionnaires

Condition	Task	Communication	Tutoring Process	Feedback Cue
collocated	1	Easy, effective usual way of tutoring. I could see facial "remarks." (more easily than vtc)	I think the approach is sound if used.	
collocated	2	Easy to use. Convenient to see expression and have quick feedback.	Approach is sound. Student had problems in the first phase, then got easier on second, then more easy. So problem was understanding what to do.	
collocated	3	easy, straight forward	sound	
collocated	4	Easy as always, just easy to be face to face	Sound for this student. Had a good statement of problem that carried him thru.	
collocated	5	excellent	sound	
collocated	6	Easy & effective. Allowed me to jump right in with helpful tips when student began to have problems	Student picked out the sin & cos off the bat (at the beginning) which was the problem.	
collocated	7	Easy, straight forward, allowed continuous interaction.	Sound approach	
collocated	8	Excellent easy method. Allowed me to pick out a Major flaw in plan that led to easy eventual answer.	Approach was sound.	
collocated cue	1	It was good	The approach is sound.	The cue seemed to not really be effective
collocated cue	2	Face to face is really convenient. It's good to be able to see faces and jump in where normally the students would not be quick to ask a question and thus he/she struggle thru.	The student drew a diagram in the ginning that really allowed me to help him. He was having probs figuring out a plan, so by him having a picture, all he had to do was identify knowns and unknowns.	The cue was not really a factor.
collocated cue	3	It was effective in continous interaction	Sound.	Did not really have an effect
collocated cue	4	Great	Sound. Got the right answer thru the right approach.	He did not use it. Said he forgot about it.
collocated cue	5	Excellent and easy	Sound	Was ok, no real impact
collocated cue	6	Easy, straight forward	Sound. Student recognized the total length as x1 +x2 but just did not do it.	The cue allowed me to curve or add help where needed which allowed for a more direct and faster solution.
collocated cue	7	The method was easy & straight forward	sound	The cue didn't change so I can't gauge if it really helped.
collocated cue	8	The method allowed me to more easily communicate the principles behind the problem.	The approach the student had was sound once the problem was understood a little better.	The cue allowed me to ask more helpful questions to the student.

Table A.29.1 Tutor's opinions from questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
email	1	The student did not use the email enough as far as actually asking questions and checking it, which gave a big gap in the tutor interaction. Maybe if the email is used more it will get better.		
email	2	Student did not use email effectively when had a question	Sound	
email	3	Not effective. No interaction in between thus allowing certain ideas and helpful hints to fall between the cracks.	Sound. Student had problem correct but just got lost in the cracks.	
email	4	Email tutoring is a waste of time. Email-send-a-question-in-get-an-answer-back is a whole different ball game. But you just can't help some learn with chopped up communication.	Approach seems sound.	
email	5	Once again, no mode of continuous interaction, took too long to interact	Approach of student was wrong.	
email	6	It was choppy. The student had problems and did not ask until I sent message asking. That wasted a lot of time. This method adds more time also with the waiting to check messages.	sound approach	
email	7	The student had right answer for like 45 min & if I was with him I could have saved that 45 minutes by hinting then. But I couldn't because student wouldn't respond;	sound.	
email	8	Too much time, no interaction	Approach was sound. Student had no earthly idea of what he was doing. Had to seriously help along because of method.	
email cue	1	The student did not use the email enough	ran out of time	The cue was not utilized effectively
email cue	2	It is not effective because student did not utilize the email correctly. Did not respond in a timely manner causing myself sever distress	sound	Didn't help
email cue	3	The email is slow. The student needs to be instructed to constantly check email once they have replied to something.	sound	The cue just let me know the student's mind set. Helped me instruct the student a little better.
email cue	4	Just not enough interaction when it comes time to answer questions. And the interaction takes too long Didn't finish session. Apparently student was not fully reading the emails when I typed at the bottom.	Approach was correct. Just bad math skills	Cue was ok

Table A.29.1 Tutor's opinions from questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
email cue	5	Just not for learning more for just answering question which is not necessarily tutoring.	student's approach was off from get go.	No help
email cue	6	It took too long to help the student. Couldn't see what student was doing, couldn't see facial expressions, just out in the dark. And the student was not using the method to the fullest.	sound.	Cue was helpful because although the student did not use email alot, I could send messages based on the cue.
email cue	7	This method sticks. The tutor sits there waiting, not being able to interject or comment on the students progress.	Almost ran out of time.	The cue just was a mental note saying how the student saw this problem
email cue	8	The process doesn't work for "tutoring". Could not get across ideas thru the email. Took too long. Not continuous feedback.	sound	The cue only let me know student mindset. Since didn't effectively use email, didn't help.
chatroom	1	Easy method. Allowed for continous interaction	sound approach	
chatroom	2	It was effective. student did not vocalize enough, but it was quick	sound	
chatroom	3	The method was ok but the student just didn't grasp the problem or it seems that he didn't	His approach was just not there form the beginning so the whole problem, I kinda had to "baby" him.	
chatroom	4	The method was easy allowing for continuous interaction	sound	
chatroom	5	It was ok	The student's approach was off and that threw off whole problem	
chatroom	6	It was easy interaction. Student was just lost on problem for the first part.	His approach became sound after a little help.	
chatroom	7	Easy & effective	sound	
chatroom	8	Method was good	sound	
chatroom cue	1	Very smooth very easy	sound	It had no real effect because the student in question really had no problems. The other 2 really used it well.
chatroom cue	2	It was nice	Sound.	The cue helped somewhat (others used it better than subject)
chatroom cue	3	Good session	Sound approach	Gave me an idea of the student's mind set
chatroom cue	4	The method was ok	Approach: students just could not visual the problem which if I was face to face I could have drawn one to greatly simplify the problem.	Cue gave me insight to mind set
chatroom cue	5	Excellent, easy and provided continuous interaction	Sound	It was semi-helpful

Table A.29.1 Tutor's opinions from questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
chatroom cue	6	Allowed to keep continuous interaction	Sound	Cue allowed me to ask more questions or stop asking questions depending on student's mindset
chatroom cue	7	Easy to use	Sound	It helped me and the student
chatroom cue	8	The method is fine if the student chooses to ask questions and participate in the chatroom. This student did not.	Approach I don't know	Student never changed cue, although answer was wrong.
video teleconferencing	1	The method was ok. I could not see her facial expression so I was kinda out there.	Again the approach seems sound. The student did not really grasp the problem from the start and that combined with some not-so-good audio made the student upset	
video teleconferencing	2	The method worked well because the student did not hesitate to ask questions, plus I could ask questions accordingly based on her facial expressions	The problem solving approach is sound. The student had a hard time in the first phase... understanding the problem. Since the student did not completely get the problem in the first place, her plan, and solving were also off.	
video teleconferencing	3	The method worked ok. Had problems understanding one another at times that made me a little frustrated. Partially came from student's accent other from audio distortion.	The approach was sound. Student jumped into problem in everyway.	
video teleconferencing	4	The student would not talk to me and was methodical in his approach so it took some time	His approach was right	
video teleconferencing	5	The method works but there is a lot of effort required that I just couldn't see someone doing all the time. Maybe if the audio was clearer and if the student utilized the method more.	The student really had no clue how to start the problem. The phase 1 was not even done correctly (had a equation)	
video teleconferencing	6	Easy & effective	Sound, had trouble in beginning, but once I mentioned trig. Student jumped right into it.	

Table A.29.1 Tutor's opinions from questionnaires (continued)

Condition	Task	Communication	Tutoring Process	Feedback Cue
video teleconferencing	7	Easy & efficient	Her approach was sound from step 1. Actually reviewed problem in stage 3 because student couldn't get to work down to x. So she asked question and just sat there thinking. And so that meant her inverse was probably wrong. Therefore we ended up reviewing as we went along. Basically mistakes copying problem	
video teleconferencing	8	The method was fine.	Sound Student can't use a calculator went over the time trying to figure at what he talking about.	
video teleconferencing cue	1	Kinda hard to understand at times	ok	It worked well because the student used it well.
video teleconferencing cue	2	It was a smooth process. I think if it was possible to see what the student was writing as well as the facial expression, the VTC would be more effective.	The approach is sound	The cue helped me see a little how the student's mind set changed.
video teleconferencing cue	3	Easy. Student utilized the equipment well, thus making the method much smoother.	Approach is sound. Student's overall approach was sound, but had a few minor mistakes.	The cue did nothing. Even with a hint, student did not utilize it well
video teleconferencing cue	4	The method worked well. Student utilized the system nicely	Try the given, find, solution step for phase 1 because the students just repeat the problem, if they do that.	The cue gave me insight about the student's mindset allowing me to ask more or less questions as needed
video teleconferencing cue	5	It was efficient	The student never started a diagram & really had no clue of how to start this problem	Worked well
video teleconferencing cue	6	It went well. Allowed for interaction	sound	Didn't do a whole lot. Gave me some insight on student's mind set.
video teleconferencing cue	7	Easy & effective	sound	It was a hint of the student's mind set regarding this problem
video teleconferencing cue	8	The method was ok.	Student's approach was off—student was lost from start	The cue was misrepresentative of actual level.

Table A.29.2 Tutor's opinions after completing all trials

Condition	Communication
collocated	Easiest method that allows the total transfer of knowledge the most convenient
collocated cue	The cue had no effect w/ the face to face because I can see expressions
email	Sucked. Terrible waste of time. You sit there forever waiting for replies and such. Good to just answer a specific question.
email cue	Same as above, but cue helps to ask more pertinent hintful helpful questions to maximize message
chatroom	Nice method if student uses it readily. If student doesn't use it, it is like email only faster.
chatroom cue	Nice. Same as above. The cue just lets me know who is not getting it or is.
video teleconferencing	Great if everything works efficiently. Sound quality is a must. If the communication is lost, so is VTC.
video teleconferencing cue	The cue helps me to visualize what is or is not on the students paper which is basically the only thing I can't see w/ the camera.

Appendix A.30 Feedback Cue Usage

Table A.30.1 Mean feedback cue usage by phase

	Phase 1	Phase 2	Phase 3	Phase 4
Mean	1.188	0.687	0.313	0.719
sd	0.397	0.896	0.535	1.464

Table A.30.2 Mean feedback cue usage by technology

	Collocated	Email	Chatroom	Video Teleconferencing
Mean	0.844	0.656	0.687	0.719
sd	1.139	0.701	1.091	0.888

Vita

PAIGE ELIZABETH SMITH

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EDUCATION

M.S., Industrial & Systems Engineering (Management Systems Engineering), May 1998
Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Thesis: Human-Centered Communication Technologies to Enhance Tutoring
Research funded by the National Science Foundation through the Southeastern University and College Coalition for Engineering Education (SUCCEED) and Minority Engineering Programs at Virginia Tech

B.S., Engineering Science and Mechanics, May 1992
Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Senior Project: Edge Notching - A Potential Method to Increase the Fatigue Life of Fiber-Reinforced Composite Laminates

EXPERIENCE

Graduate Assistant, Office of Minority Engineering Programs (OMEP), Virginia Polytechnic Institute and State University, Blacksburg, Virginia (August 1995 – Present)

- Assistant Director and Coordinator of ASPIRE '97 (a five week summer bridge program for incoming engineering freshmen)
- Academically advise and support engineering students at all academic levels
- Collect, analyze, and report retention, attrition, and matriculation data for minority students in the College of Engineering
- Assist in recruiting high school students to the College of Engineering
- Assist in coordinating and implementing Faculty of the Future, a bi-monthly seminar for juniors and seniors in the College of Engineering interested in pursuing graduate studies
- Write proposals for funding to support the various student retention efforts of the Office of Minority Engineering Programs
- Instructor, Manufacturing Engineering Program for Young Scholars funded by the National Science Foundation (a camp for rising senior high school students interested in Industrial and Manufacturing Engineering) (Summer 1996)
  - Developed and gave class lectures on statistical quality control
  - Developed and ran laboratory sessions where the students could practice concepts
- Virginia Tech Academic Success Program (VTASP) committee
- Designed office layouts

August 1992 - August 1995

- Academically advised freshman and sophomore engineering students
- Conducted professional development seminars for freshman engineering students
- Coordinated the College of Engineering's Student Assistance Center
- Recruited high school students to the College of Engineering
- Served on VTASP committee
- Co-directed and co-founded Women in Engineering, a support program for women in engineering
- Director and Coordinator of the Academic Enrichment Camp (a two week summer mathematics and science camp for rising seventh and eighth graders)

Graduate Teaching Assistant, Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, VA, Summer 1992

- Graded homework assignments and weekly laboratory reports for Mechanics of Materials Class and the associated laboratory

Pre-professional Nondestructive Test Engineer, Newport News Shipyard and Dry Dock Company, Newport News, VA, Summer 1991

- Identified potential structures in submarines to be replaced by composite materials
- Evaluated the shipyard's ability to nondestructively test composite material structures
- Targeted future nondestructive test methods to be added to the shipyard's capabilities

Intern, United States Department of Agriculture, Beltsville, MD, Summer 1990

- Programmed food testing procedures in C
- Converted existing FORTRAN programs to C

PROFESSIONAL & ACADEMIC ACTIVITIES

- Alpha Pi Mu, Industrial and Systems Engineering Honor Society, Spring Semester 1996 - present
- Graduate Student Representative to the Women's Engineering Board of the SUCCEED National Science Foundation Coalition, 1992-present
- Student Member, American Society for Engineering Education, Fall Semester 1997 - present
- Student Member, Institute of Industrial Engineers, Fall Semester 1997 - present

PUBLICATIONS AND PRESENTATIONS

- National Association of Minority Engineering Program Administrators, co-presented a paper on Focus Groups (San Francisco, CA: January 1996)
- Smith, P. E., and Kleiner, B. M. (1996). A framework for optimizing a virtual learning system for minorities and industry in the field of engineering. International Engineering Management Conference Proceedings, Vancouver, Canada: 635 - 640.