THE EFFECTS OF FREQUENCY AND QUALITY OF INTERACTIONS IN A COMPUTER-BASED LEARNING SYSTEM

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(ABSTRACT)

The word "interactive" is used commonly when describing many teaching, learning, and training software. Yet, this word does not provide a clear picture to the users what interactivity will provide. In order to better define and understand how, and if at all, interactive software affects learning, this study examined different components of interactivity.

Two components of interactivity, frequency and quality, were used in this study. Much of the literature describe and provide comments that interactive learning is "good," but none seem to examine the components of interactivity within an empirical research study. Therefore, this study examined frequency and quality of interactivity in a human factors experiment using a Web browser and a computer simulation game. This study seems to be one of the first to experimentally investigate and test components of interactive learning.

The two components of interactivity both had two levels and therefore were varied factorially as four different types of learning materials. After going through the learning materials, each participant in the study had to go through two different testing methods. The first method was a traditional paper test of knowledge, and the second method was applying the knowledge in the computer simulation game. The latter is considered analogous to applying learned information at a workplace.

The results showed neither frequency nor quality to be significant. But, the interaction of the two components showed significance. The results lead to the conclusion that interactivity is more than one dimensional. One component alone will not alter effectiveness, but the right combination of components can provide an effective interactive learning material.

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TABLE OF CONTENTS

LIST OF TABLES

List of Figures

List of Equations

INTRODUCTION

> "The word Education is used with many meanings, but in all its usages it refers to *changes*. No one is educated who stays just as he was. We do not educate anybody if we do nothing that makes any difference or change in anybody. The need of education arises from the fact that *what is* is not what *ought to be*."
>
> (Thorndike, 1906).

Throughout the history of human kind, people have been fascinated with knowledge and learning. Much of what people know and how people think is due to many different paths of learning and training in a variety of environment, whether it be in academics or real world situations. Whatever the situation a person is in, he/she needs certain knowledge to survive and/or succeed in life. What is unequal in life is that one person achieves more than another in the same amount of time. Of course there are many reasons why that occurs, ranging from innately given abilities to monetary reasons, but one thing that can be controlled is the medium in which the learner is exposed.

Despite vast amounts of information to be learned and the importance of obtaining knowledge in today's rapidly changing society, the way people are taught is relatively unchanging. "This strategy for learning that dominates today is old. It has changed little over a long time, in spite of the talk of new media and new approaches that permeates the literature" (Bork, 1992). The lecture method with teacher focused learning is used worldwide, ranging from small children in Japan to students in the United States (Bork, 1992).

So why has the pedagogical technology (Bostow, Kritch, and Tompkins, 1995) not changed much? Perhaps because that is how the teachers themselves were taught and the "chalk and talk" method is so widely used (Bostow et al., 1995).

At present, technology and media are available to foster better teaching and learning; in particular, computers. With the power of computers increasing and prices dropping rapidly, the higher technology-based learning is becoming more readily available. Yet, people have not been taking advantage of the available pedagogical technology (Bork, 1986, 1992; Schank, 1993; Schank, Korcuska, and Jona, 1995).

"Many believe that the computer, although poorly used in education to this point, has great potential for making massive improvements in learning for almost everybody in the world"

(Bork, 1992). The great potential is in using computers as an interactive learning tool that will adapt to each individual learner (Bork, 1991, 1997; Bostow et al., 1995; Clark and Salomon, 1986; Schank et al., 1995).

Not only do computers have great potential as learning media, but they are prevalent and are used extensively by people today. In 1992, sales of home learning software programs reached $147 million, and by the end of the decade, parents will be spending about $1 billion a year on software for home learning (Armstrong, 1994). The software purchases made by schools in the U. S. was estimated to top $1.45 billion in 1996 (Economist, 1994).

Information and knowledge are accessible in many forms today (e.g., in books, video, audio, and computers). An important and necessary research area is not only in creating more technically sophisticated media but in how to efficiently obtain and retain the available knowledge in such media.

> "The art of teaching may be defined as the art of giving and withholding stimuli with the result of producing or preventing certain responses."
>
> (Thorndike, 1906).

Theoretical Background

Human Information Processing and Learning

Before examining what it means for learning to be interactive, a brief understanding of how humans process information when they learn is needed. In order for any information (or knowledge) to be understood and learned, there are several stages through which it needs to go. Information gets encoded, stored, and retrieved for it to be effective knowledge. The three stages of memory (Wickens, 1992) presented in Figure 1 are:

(1) *Encoding, learning, or training*. The issue of how information can be permanently stored in the most efficient manner leads us to the issue of *transfer*: how knowledge learned in one context facilitates the learning of new material.

(2) *Storage* or *knowledge representation* leads to the issues of knowledge organization and mental models.

(3) *Retrieval failures*, *forgetting*, and *retention* leads to what sorts of memory errors people make on retrieval and how forgetting occurs. (Wickens, 1992).

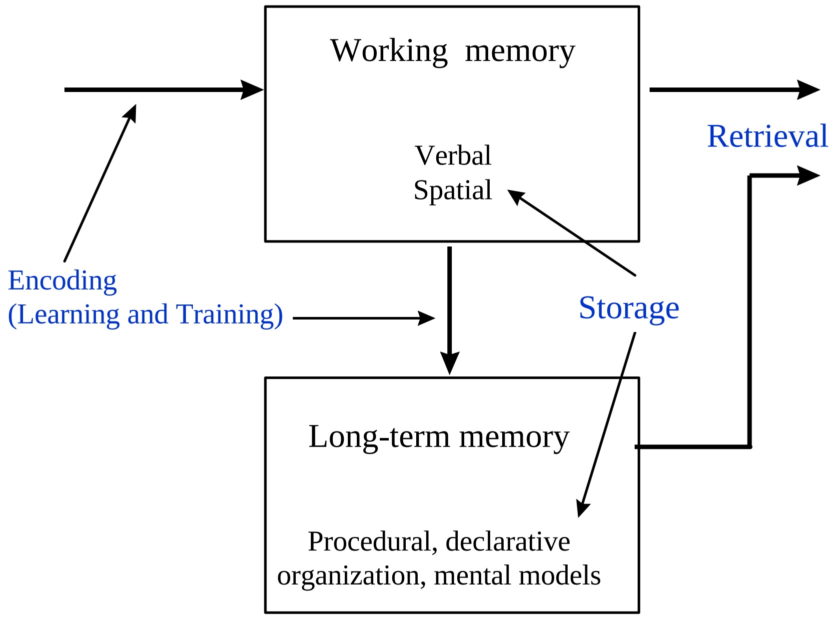

Figure 1. A representation of memory functions (Wickens, 1992).

Figure 1 graphically illustrates that a stimulus (e.g., a learning content) encoded in the beginning can later affect how that information will be stored and retrieved.

Strategies of Learning/Training

After realizing how learning and information might be processed for humans, some strategies that suggest easier and better ways of encoding may be helpful in learning. Wickens (1992) mentions seven strategies that may enhance learning:

(1) *Practice and overlearning*. "Practice makes perfect" but how much practice is not always clear.

(2) *Elaborative rehearsal*. Rehearsal is an active process, necessary to maintain chunks of information in working memory.

(3) *Reducing concurrent task load*. Subtasks will compete for resources from main tasks and with one another. Effective learning will not take place in a high-work-load environment.

(4) *Error prevention*. Making sure the learner does not stray too much and provide correct information.

(5) *Adaptive training*. Reducing the initial level of difficulty so that the learner can gradually adapt to the desired level of performance.

(6) *Part-task training*. Where elements of a complex task are learned separately.

(7) *Knowledge of results*. Providing the learner with knowledge of results or feedback about the quality of performance.

Knowledge Organization and Mental Model

Information in long-term memory has distinct structure and organization, and it is not simply stored as random facts (Wickens, 1992). Therefore, to aid learning with proper storing, information should be such that it has good organization and representation.

"The organization of knowledge about how a system works or operates has been described as a *mental model*" and a correct mental model can be advantageous to the user when other learned knowledge fail (Wickens, 1992). Norman (1988) defines mental models as "the models people have of themselves, others, the environment, and the things with which they interact." In the case of interactive learning, Jih and Reeves (1992) think the functionality of the learners' mental models affects the quality of interaction in Interactive Learning Systems. Therefore, the designers of learning systems should consider organizing knowledge such that it would be matched to the learners' mental models for a more effective learning session.

Transfer of Training

An important factor when learning a new skill is the concern of how much that new learning will transfer to the actual task. Measuring transfer of training is normally used to evaluate the effectiveness of different training strategies (Wickens, 1992). For example, how much will learning to fly on a flight simulator transfer to actual flying of an airplane?

The measuring of transfer of training can be done using a control group. In this case, the people who are in the control group will not get any training and their performance will be measured. For the transfer group, they will be given certain amount of training and their performance will be measured.

One measure of transfer of training is by determining the percent of transfer which is shown in Equation 1.

$$\% \text{ transfer} = \frac{(Y_C - Y_X)}{Y_C} \text{ X } 100 = \frac{\text{savings}}{Y_C} \text{ X } 100 \qquad (1)$$

Y_C = time, trials, or errors required by a control group to reach a performance criterion
Y_X = corresponding measure for an experimental, or transfer, group having received prior practice [or training/learning] on another task

Equation 1. Percent Transfer (from Roscoe, 1971,1972; and Wickens, 1992).

For example, if Y_C was 5 hours (i.e., time for the control group to complete the task) and Y_X was 4 hours (i.e., time for the trained group to complete the same task), the Percent Transfer would be 20 %. If the Percent Transfer value obtained from the above formula is a positive value, then there was some saving of time in performing the task due to training. But, if the Percent Transfer value is a negative value, then due to training, there was a loss of time in performing the task. Therefore, in general, a positive percent of transfer is desired from a training program.

Even if the Percent Transfer value from training is positive, that does not necessarily show the effectiveness of the training program. In the example above, where Y_C was 5 hours and Y_X was 4 hours, the percent transfer was positive; the time to complete the task for the trained group decreased by 1 hour when compared to the group with no training. But, what if the training took 2 hours? The amount of time saved to complete the task (with training) is less than the time to train; in this case, no training would have actually saved more time. Another measure is needed to determine the effectiveness and efficiency of the training program.

Roscoe (1971) proposed several functions to measure transfer of learning. In the current study, the Cumulative Transfer Effectiveness Function (CTEF) (Roscoe, 1971) was used as shown in Equation 2.

$$\text{CTEF} = \frac{Y_O - Y_X}{X} \qquad (2)$$

Y_O = same as Y_C in equation (1)
Y_X = same as Y_X in equation (1)
X = time, trials, or errors by an experimental, or transfer, group during prior or interpolated practice on another task [the amount of training time, trials, or errors for the control group]

Equation 2. Cumulative Transfer Effectiveness Function (from Roscoe, 1971,1972).

Therefore, in cases concerned with training time, the CTEF basically compares the amount of time saved in performing the desired task from training to the amount of time spent in training. If the

CTEF has a value greater than 1, then the amount of time saved due to training is greater than the amount of time spent in training. If the CTEF has a value less than 1, then the amount of time saved in performing the target task is less than the amount of time spent in training. So, greater the CTEF value, more efficient is the training.

> "Given this material for education and this aim of education, what means and methods shall I use?" (Thorndike, 1906).

Media of Learning

Multimedia Benefits and Media Comparison

There is a recurring expectation from new media in teaching that student motivation and performance may be enhanced by them (Clark and Salomon, 1986). More and more budgets for institutions are allocated for purchasing computers and other technical equipment. There is an emphasis with technology in education towards augmenting number of equipment (Bork, 1997).

It becomes more important and necessary to study media in teaching and training. Clark and Salomon (1986) suggests two research possibilities: (1) discover what is known about the utility and effectiveness of media for instructional purposes and (2) the recent explosion of interest in the computer as an instructional tool requires examination of the lessons learned from previous media and apply them to the study of new ones.

The evidence toward different media providing effective learning is mixed. With over 70 years of media comparison research in several countries, there is no agreement among researchers on the answer (Clark and Craig, 1992). One reason for the mixed results is that "in this mix [mix of interactions between specific tasks, learner traits, and various components of medium and method], the effects of gross, undifferentiated 'medium' variable could not be productive" (Clark and Salomon, 1986). Decades of research in media comparison suggest that there are no learning benefits from employing different media in instruction, regardless of their attractive features or advertised superiority (Clark, 1983; Clark and Craig, 1992; Clark and Salomon, 1986). In recent media comparison studies, independent of the media employed, the results had the tendency to show no significant differences (Clark and Salomon, 1986).

In cases where one medium was found to be superior over another, confounding and uncontrolled variables could explain their results (Clark, 1983; Clark and Craig, 1992; Clark and Salomon, 1986). Some benefits were due to more attention given to the new medium by the designers and the novelty of the new medium (Clark, 1983). Despite the focus of study often times being on something other than media, some interpretations of results wrongly suggest learning benefits were derived from various media (Clark and Salomon, 1986). For the future, Clark and Craig (1992) suggest not to continue multi-media research and application based on expected and presumed learning benefits and cease future research in media comparison unless a clear theoretical reason to expect learning gains due to any characteristic exclusive to a certain mix of media.

Petitt (1994) investigated three different media (text-based, standard multimedia, and multimedia simulation learning systems). From his study, Petitt (1994) found that through performing Analysis of Variance (ANOVA), the Method of Instruction (the three different media learning systems) was statistically significant. When further post-hoc test was performed, Petitt (1994) found that the standard multimedia instruction was found to have significantly better original learning than the control condition (text-based instruction), but the multimedia simulation instruction was not found to have significantly better learning than the control condition. One of Petitt's expected results was that the multimedia simulation instruction would have better original learning than the standard multimedia instruction, but the study showed the opposite (Petitt, 1994).

In a similar study to Petitt's (1994), Ramsey (1996) examined three different learning media (text-based and two multimedia instructional systems) and retention of learning in the media. Consistent with many of the findings mentioned previously, Ramsey (1996) did not find any significant results from her study.

Including two relatively recent studies in multimedia instruction comparisons, (Petitt, 1994, and Ramsey, 1996), the results generally do not show consistent significant difference favoring one medium over another. The inconsistency in results suggests that learning cannot be determined effective or not only with the medium it is utilizing. Further studies need to focus on what aspects of the medium and what aspects of learning actually affect learning. Therefore, this study focused on using only one medium and varied components of interactive learning to determine the effectiveness of those components.

Learning Media

Since the advent of advanced technology, the number of media available for learning has greatly increased. Despite numerous available media for delivery of education, the "major learning modes in schools and universities are the lecture and textbook" (Bork, 1997). Some of the media available today are shown in Table 1.

Table 1. Different tools available currently for training (adapted from Tucker, 1997).

Ways of Delivering Training	**How the Media Are Used**
1. Computer-Based Training	CBT is the generic term for training delivered, tested or managed by a computer.
2. Interactive Audio	Can be used in teaching language via CD-ROM on a computer.
3. Interactive Video	Same idea as Interactive Audio.
4. Digital Video Interactive	Similar to Interactive Video but since the data is in digital format, it can run video at controlled variable speeds. It also allows a frame or frames to be altered by changing pixels.
5. Expert Systems/Artificial Intelligence	Used to help trainees to learn by discovery. No forced route through the system.
6. Multimedia	Usually a combination of several media (e.g., text, graphics, sound, video) used on personal computers.
7. Hypermedia	Non-linear form of navigating through information with nodes and links on computers (e.g., the World Wide Web).
8. CD-ROM	Compact Disc Read Only Memory is a storage device of information such as audio and video.
9. Compact Disc Interactive	Whereas CD-ROM needs a PC and a computer monitor, compact disc interactive (CD-i) only needs a player with on-board and a video or television monitor.
10. Digital Video Disc	Will be able to hold 8 times as much as the current CD-ROM.
11. Simulation	Computer programs used to mimic or copy real life situations.
12. Virtual Reality	Similar to simulation but one level up from simulation. Some aspects associated with it are 3D graphics, audio, and immersive environments.
13. Video Conferencing	Uses video cameras and monitors with usually with multiple-channel telephone links for audio.
14. Desk-To-Desk Conferencing	Similar to video conferencing but with PCs and smaller cameras.
15. Satellite Broadcasting	Used to send and receive messages over the satellite at distances far away from current position. Distance learning at universities is an example.
16. Networks/Internet/Intranets	Also known as information superhighway. Uses modems or network connections on computers. World Wide Web is an example.

Computer-Based Instruction via the World-Wide Web

Of the available technology-based tools for learning, computer-based instruction was chosen as the learning medium in this study. One major reason for looking toward the World-Wide Web (WWW) as a learning tool was that it is popular today and its acceptance in our culture is growing everyday. The estimate of people who use the Internet is about 40 million and is expected to grow to 200 million by 1999; and through the 1990s, the annual rate of growth for the WWW traffic is 341,000 % (Benen, 1998).

There are already a number of Web sites used to teach people. The designers and creators of these sites exist in the commercial world and many in educational institutions. "The potential impact that the WWW will have on psychology and psychological education extends far beyond serving as a resource for information acquisition" (Krantz and Eagley, 1996). Krantz and Eagley (1996) think that interactive reader-oriented tutorial with ability to combine multimedia and the ease of availability of the learning material on the WWW are compelling reasons to use this medium in education. At Claremont Graduate School in Claremont, California, a Web based learning project is used for statistics education (Aberson, Berger, Emerson, and Romero, 1997). Aberson et al. (1997) believe the following:

(1) Thought-provoking questions should be asked of students to stimulate interest and a deep processing of information.

(2) An environment should exist where the mistakes can be made without risk of penalty.

(3) The opportunity to learn in a highly individualized manner, wherein specific mistakes and misconceptions can be properly addressed.

(4) Immediate feedback should be available regarding the accuracy of answers.

(5) Topics should be presented in multiple ways, providing the student with more than one representation of complex concepts.

Using the previous concepts together on the WWW can meet many educational goals (Aberson et al., 1997).

Another reason for choosing the WWW as the learning medium in this study was that it can incorporate many other media to teach and instruct people. The WWW can use graphics, video, audio, and certainly text. In fact, many Web sites currently use mixture of many media including animated figures.

Summary of Computer-Based Instruction as a Potential Learning Medium

Reviewing how humans process information, learning strategies, and available forms of learning delivery systems, common desired qualities for an instructional system arise. They are as follows:

- Easy repeat and rehearsal of the material to assure learning.
- Readily available verbal and spatial (e.g., graphics and sound) information to better encode knowledge in working memory.
- Immediate knowledge of results (i.e., feedback) to reduce future errors
- Adaptable to the user and individually paced
- Mistakes can be made during learning without risk of penalty
- Can incorporate other media such as text, graphics, audio, video, and animation
- Provide easy access to many different learners at different times or anytime
- Interesting
- Interactive learning

And, the WWW seems to hold the above qualities. Then, the next question one has to ask is, "Will the medium chosen to teach meet the demands of the desired qualities in learning?"

In order for this potential medium to reach its full capacity, it must be carefully studied concerning many aspects of the system. What good is a learning program on the WWW when it only presents copied text a book?

Interactivity of Learning

What Learning Should Be

Many people hold many different views on what learning should be. Here are some suggestions of what learning should be. First, Bork (1992) gives five suggestions on developing an effective learning media. The five suggestions are as follows:

(1) *All Students Should Learn Everything.* Learning should be democratic and everyone should have the right to be immersed in the best possible learning environment to facilitate learning.

(2) *Learning Should be Interesting*. Learning should be interesting to the learner and thus provide motivation and encouragement to learn more.

(3) *Learning Should be Active*. Learner should not be a spectator but an active participant who will be engaged in the topic of study and be guided toward the correct path when wrong steps are taken.

(4) *Learning Materials Should Use Many Media*. Learning should use the great variety of media available to find what the student is actually learning and to govern further learning from those experiences.

(5) *Learning Should Be Individually Paced*. Learning should be available and vary at individual paces tied in closed with interactivity and motivation.

Schank et al. (1995) also lists four fundamental features of natural human learning. They are as follows:

(1) Learning is *goal-directed*. People are both willing and able to learn while they are pursuing a goal of interest to them.

(2) Learning is *failure-driven*. Mistakes are the triggers that people naturally use to recognize that knowledge is lacking and that learning needs to occur.

(3) Learning is *case-based*. When confronted with a problem, people naturally think back to similar situations they have encountered that might help them solve the problem.

(4) Learning occurs naturally when it is tied to *doing*. Learning-by-doing helps ensure that people will be able to use what they learn.

Learning Should Be Active or Interactive?

Many people propose that learning should be active, and therefore, the learner should learn by doing (Bork, 1992; Schank, 1993; Schank et al., 1995). What if the learners are active in doing the wrong things? What learning really should be is *interactive*. The teacher and the student should be able to provide continuous feedback to each other for better and more effective learning session.

The word “interactive” is used widely to describe many educational software and tutorial programs What exactly does interactive mean?

Defining "Interactive"

The Oxford Dictionary of Current English (1996) defines *interactive* as 1) reciprocally active and 2) (of a computer or other electronic device) allowing a two-way flow of information between it and a user. Milheim (1995-96) defines interactivity as the two-way communication between learners and the educational materials. Therefore, in order for something to be interactive, it has to be reciprocally active and information has to flow both direction between at least two entities.

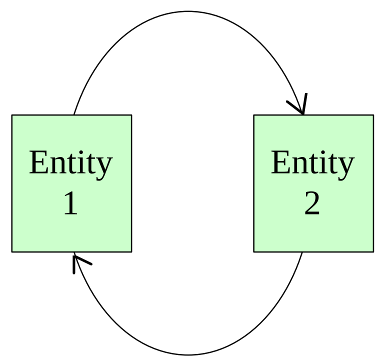

Figure 2. Simple graphical view of interactivity.

Although the word interactive is easily defined and known by many people, many seem to forget what it means and often times misuse the word. As an excuse for selling, purchasing, and using computer-based instructional systems, the word interactivity is often used and misused today (Weller, 1988).

Interactive Learning

By employing interactive learning, a promise of better learning via learner-center and immediate correction of mistakes acquired knowledge leading to better encoding of information into working memory and better retention is made. With the assumption that interactivity can be beneficial, how does one measure how interactive a learning material is? "There is a great deal of talk of interaction—interactive computer material, interactive video, interactive multimedia—but little discussion of how interaction is to be measured … It is not simply a case of whether the material is interactive, or not interactive, but of HOW interactive" (Bork, 1992).

In spite of numerous learning and training programs claiming to be interactive, there is minimal amount of empirical research studies on this topic. Surprisingly, with much literature being proponents of interactive learning, there are very few articles being written about detailed aspects of interactivity. Although the topic of interactivity is scarce, the idea of it is "intuitively appealing" (Borsook and Higginbotham-Wheat, 1991). The notion of interactivity is not well defined, especially for computers and their significance in teaching (Borsook and Higginbotham-Wheat, 1991).

Even fewer number of literature is available when it comes to empirical research in examining interactivity in instructional systems. Only a few articles were available that actually looked interactive learning systems.

Schaffer and Hannafin (1986) studied different types of interactivity on learning from an interactive (multimedia) lesson. The four different treatments in the study were (1) video only, (2) video and embedded questions, (3) video and questions with feedback, and (4) all of the functions from the previous three plus ability to go back to previous video sections when learning was not demonstrated. A couple of interesting findings from the study were that there were indeed significant effects from the amount and type of interactivity; from the fully interactive questioning, the highest level of recall was found.

In another study by Summers (1990-91), similar treatments were given using interactive video (multimedia), but no significant results were found. One interesting thing is that the participants in the study showed significant preference for the interactive videodisc.

Interactive Questioning

One interactive method in teaching is to use questions for helping learners better encode and retrieve their learning. Studies reviewed by Slater (1997) show positive signs for interactive questioning such as better recall of main ideas, more attention from learners, and better encoded information that can be used more readily.

Carin and Sund (1971) lists several ways in which questions can be used to:

(1) Arouse interest and motivate children to actively participate.
(2) Evaluate a student's preparation and to check understanding of assignments.
(3) Diagnose strengths and weaknesses of a student.
(4) Review and/or summarize the presented material.
(5) Encourage discussion.

(6) Direct children to new possibilities in problems being explored.

(7) Stimulate students to seek out additional information.

(8) Build up a positive self-concept for a student.

(9) Help children to see applications for learned concepts.

(10) Assess the success of goals and objectives of the teacher's lesson.

The method of questioning has been used by educators for thousands of years to reemphasize learning and to get feedback from students to determine what has and has not been learned. This type of method is also popularly known as the "Socratic method" of teaching because Socrates also used questioning methods to teach his students.

Measure of Interactivity

"Rather than creating problems to which we apply our most popular interactive technology, we need to develop design processes which identify the required components of interactive, adaptive instruction" (Jonassen, 1985). In order to create interactive instructions, the components of interactivity must be carefully examined and defined. Jonassen (1985) suggests that there are five analyzing levels of interactivity arranged in order from specific to general (Modality of Interaction being the most specific):

(1) *Modality of Interaction* - Interaction occurs at the level of sensory systems such as visual and auditory modalities.

(2) *Task Analysis* - Analyzing the nature of the learner interaction through conducting a task analysis of the learner's behavior.

   A. Task Level - Separated into basically two tasks: "a remember task" where only recall of facts is required and "a use level" where learners use (apply) knowledge.

   B. Content Level - The type of information being processed.

(3) *Level of Processing* - After perception and recognition, information processing involves a greater degree of semantic and cognitive analysis. Interactive instructional design should encourage the learner to have more elaborate mental representations than reflexively responding to information on a screen.

(4) *Type of Interactive Program* - Different types might be drill-and-practice, tutorial, problem-solving, simulation, or mixed-initiative, knowledge-based programs.

(5) *Level of Intelligence of Design* - Looking at the intelligence of the interactive systems such as how they are respond to the learners.

Borsook and Higginbotham-Wheat (1991) also have their “ingredients” in “recipe for interactivity” as follows:

(1) *Immediacy of response*. How fast the instructional system responds.
(2) *Non-sequential access of information*.
(3) *Adaptability*.
(4) *Feedback.*
(5) *Options*. Interactive system should have many options available for learners.
(6) *Bi-directional communication*.
(7) *Grain-size*. Refers to the length of time required of a given sequence before allowing further input [frequency of interaction].

Also, Milheim (1995-96) and Weller (1988) see interactivity having components of *quantity* and *quality* of interactions. Quantity referring to number of interactions and quality referring more to the learner being able to control more of the interactions within the lesson.

According to Bork (1992) *degree* and *quality* of interaction are aspects of interaction that should be considered because they have a promise of being represented quantitatively. The degree of interaction also can be defined as the number of interactions that occur and compared to the total learning process. If a student asks questions perhaps once every month in a crowded lecture hall, there is a very little interaction for that student. The frequency of interaction is one way to measure interactivity.

Quality of interaction is a more complex topic (Bork, 1992). Whereas, in the degree (frequency) of interaction, quantitative approach is possible, quality of interaction is difficult to quantify. Some interactions definitely seem to be of low quality but only through intuition rather than measurable quantity (Bork, 1992). One way to look at quality of interaction is to see if the interaction is meaningful at all.

Summary of Literature

The human information processing model describes the sensory input of learning that occurs via different modalities such as visual and auditory. This information then can be organized and practiced to help better retrieve later using certain learning strategies.

There are many media available today in which learning instructions can take place, but which medium is better than another is a difficult question to answer. Previous research has shown mixed results, leaning more towards no single medium being more effective than another.

Learning, training, and educating are important with the amount of attention it receives from all fields of our society ranging from educators, businesses, to the government. The "hot" topic of today is learning with computers. But, the focus is more on equipment than how effectively that equipment should be used to teach. More specifically, interactive learning is mentioned widely today. Despite the popularity, no one really knows exactly what it means for an instructional system to be interactive and what components exist in interactive learning. Much of the literature mention interactive learning being good and that it should be used, but not many literature discuss empirical studies examining and suggesting what constitutes a learning system to be interactive.

Only a minimal amount of literature on learning examines different levels and components of interactivity. Of these few, two components of interactivity seem to posses potential (i.e., their ability to be manipulated in an experiment) to be used in empirical research. They are: (1) Frequency of Interaction and (2) Quality of Interaction.

Problem Statement

The prevalence of computers and different forms of media today provide the opportunity to use such systems to aid learners of various backgrounds and abilities. Yet, this potential has not been fully used and explored. One such medium, the WWW holds great potential to teach and train vast number of learners using its encompassing power of other multi-media. Combining the WWW, as the medium, and interactive teaching, as the tool, may provide effective learning. The problem with interactive learning is that the components of interactivity have not been well defined with very few empirical studies supporting that interactive learning actually works. Therefore, the focus of this study is to:

(1) Determine and examine different levels of Frequency of Interaction and its effect on learning effectiveness.

(2) Determine and examine different levels of Quality of Interaction and its effect on learning effectiveness.

(3) Determine if learning from a Web-based instruction will transfer to a computer simulation of goal-directed dynamic decision making tasks.

Method

Experimental Design

A 2 x 2 between-subjects design was used in this study. The two factors used were (1) Frequency of Interaction and (2) Quality of Interaction. Frequency of Interaction had two levels (i.e., low and high). Quality of Interaction had two levels (i.e., low and high). There also was a control group that did not receive any learning material. Therefore, there were a total of five different treatment conditions. The cell size of 10 (i.e., n = 10) was determined by using the same number as two previous theses (i.e., Petitt, 1994 and Ramsey, 1996) from Virginia Polytechnic Institute and State University.

		Frequency of Interaction	
		Low	High
Quality of Interaction	Low	n=10	
	High		

Control Group

n = 10

Figure 3. Experimental design for the study.

The interactive part of the learning material was defined as the questioning sessions that came up while going through the learning material. For Frequency of Interaction, learning material varied in the number of questions asked when an interaction occurred. After a certain amount of learning material was provided, questions were asked to test learners what has been just covered. Since there was no previous research conducted on manipulating Frequency of Interaction in a learning system, the two levels of Frequency of Interaction was determined by counting the total number of words in the learning material, excluding the interactive questions. The total number of words in one learning material was 3028 words. For the Low level of Frequency, only two interactive questioning sessions were provided. First half of the Low Frequency material had 1334 words, and the second half had 1694 words. For the High level of Frequency, four interactive questioning sessions were provided. The first quarter of the High

Frequency material had 758 words, the second quarter had 576 words, the third quarter had 854 words, and the fourth quarter had 840 words. The interval for the frequency of questioning depended on the amount of information given (i.e., number of words) and not on time. Although the number of words could be evenly split, the reason for it not being evenly split was to ensure that an interactive questioning session would not break up and disturb readers in the middle of reading a chapter or a sentence. With that in mind, the number of words was split as evenly as possible.

For Quality of Interaction, the delivery of feedback varied in the learning materials. In the Low Quality of Interaction case, when the interactive questions were answered by the learners, the correctness of the answers was simply given as text on screen. In the High Quality of Interaction case, when the questions were answered, the correctness of the answers was given visually with a more animated feedback as well as auditory feedback was provided. Also, next to each question, an option of displaying a more detailed reason of why the mistake happened was given. Therefore, the two basic differences between the two levels in Quality of Interaction are (1) visual feedback alone vs. visual, auditory, and animated feedback and (2) availability of option to understand and correct previous mistakes.

Controlling for Confounding Variables

Several factors in this study were controlled for confounding. They are as follows:

(1) The contents of all the learning materials were the same.

(2) The questions asked during the learning sessions were the same for all the treatment groups.

(3) The medium used to present all the learning materials was the same.

(4) Only differences for the learning materials were the Frequency and Quality of Interaction.

(5) All the participants performed the same task, excluding the control group that did not receive learning and the written test.

(6) The participants (meeting the set criteria described below) were chosen randomly.

(7) The treatment order was set before the participants were chosen to make sure the investigator will not be biased in giving a certain treatment to a certain participant.

Participants

The participants were recruited from Virginia Polytechnic Institute and State University campus and Blacksburg. Fifty participants with age of at least 18 years old and enrolled in Virginia Polytechnic Institute and State University as a student were recruited. The criteria for the participants were that their native language is English or proficient in English, have never played the computer simulation game used in this study (i.e., Age of Empires™), and have at least 20/50 normal or corrected vision. The participants' vision was examined using The Bausch & Lomb Vision Tester. The criterion for the 20/50 vision was determined by calculating the visual angle of the smallest character width that the participants had to see on the computer screen.

Development of the Learning Material

Four different learning materials were developed. See Appendix F for sample screen displays. All of the contents in the learning materials were the same to keep the study focused on different levels of interactivity and to ensure no one learning material was biased by having more information than another. Frequency of Interaction and the Quality of Interaction were the only things that differed among the four learning materials.

The format of the interactive questions was multiple choice. Since there were a total of four treatment conditions for the learning groups (2 x 2 between-subjects design), there also were a total of four different learning materials. The learning materials were developed specifically to be used in a Web browser called Microsoft Internet Explorer 4.0. Microsoft FrontPage was used to develop the Web-based learning materials.

The content of the learning materials was based on how to play the computer simulation program. Since the participants in the study did not know anything about the simulation program prior to the experiment, they needed to be informed about various aspects of the program. In the computer game, goals for the participants to achieve were given. Therefore, the content also depended heavily on knowledge needed to obtain those goals. Much of the knowledge learned was procedural information and minimal amount of strategy on how to better use the procedural information.

Also, participants in the four experimental groups were given exactly the same amount of time (i.e., 30 minutes) to go through the learning materials. This was to make sure that all the groups had equal amount of learning chances before they went onto using their learning in the testing environment.

Computer Simulation Game Environment

There are many instances in the real world where learners have to use their learned knowledge to make decisions and face consequences and benefits of those decisions. For example, in the military, soldiers are briefed about tactics and information about their missions and have to make decision and perform with the given information. In the computer game, the learners were tested on how they would apply their learning to achieve a goal.

The computer simulation program that was used in this study is called Age of Empires™ by Microsoft. See Figure 4 for a screen display. The objective of the program was to accomplish the set goals. The player of the simulation program basically controlled a colony of people to perform different tasks (e.g., chopping down trees to gather wood and use the wood to build houses). Whether the goal be defeating nearby colonies or obtaining certain amount of wealth, the user of this program had to control many different units, not unlike the command and control systems in the military.

The task environment also was developed by the investigator of this study. Age of Empires™ provides a convenient "scenario editor" where different goals and settings can be developed. The task environment was first developed and the learning materials were developed according to the necessary knowledge needed to perform the set goals.

Figure 4. A screen display of Age of Empires™.

Apparatus

Both the learning and the task environment were developed and tested on a 166 MHz Cyrix chip PC, and tested and performed the experiment on a 133 MHz Intel chip Pentium PC. The monitor screens' diagonal size was 17 inches. The screen addressability for the learning and the task environment was 800 x 600. The testing of participants' vision was done on The Bausch & Lomb Vision Tester along with the instruction manual (Catalog No. 71-22-41) for the machine.

Procedure

Before the experiment began, participants were screened to ensure that they had never played Age of Empires™, were at least 18 years of age, were proficient in English, and had at least 20/50 normal or corrected vision. Afterwards, the participants were given the informed consent form to read and sign as shown in Appendix A. After signing the form, all the participants went through a brief session where they were taught the basic maneuvers of the game. Since the control group knew absolutely nothing about the game and was not receiving any training, three basic maneuvers were taught to them. Since all the participants needed to have the same amount of information before the game began, they were all taught those basic maneuvers of the game. Then, the participants were either given one of the four treatment conditions to go through the Web learning for 30 minutes or no learning if they were to be in the control group. Immediately following the learning (if in the four experimental groups), they were given the written test as shown in Appendix B. Afterwards, the participants started to use the computer simulation program. The goals of the computer simulation program were given on the screen of the program, right before the task began and timing started. When the participants pressed the "start" button on the screen, the task began and time was automatically recorded by the computer until the desired goals were reached. The same steps were taken by all fifty participants in this study.

After the computer simulation program ended, each participant was given a questionnaire, as shown in Appendix C, to provide opinions on the appropriateness of the learning material, medium, and the task environment.

Dependent Variables

There were two sets of dependent measures collected in this experiment. The first set of measures focused on the written test scores. After the four training groups went through the learning, they were required to take the written test. Only the control group did not take the written test because they did not receive any learning.

The second set of dependent measures focused on the time to complete the computer game. After the written test, the four learning groups were timed on completing the computer game. Also, the control group was timed on completing the computer time. From the computer game, there were additional minor dependent measures collected and are as follows:

1) number of enemies killed,
2) number of razing (i.e., enemy buildings destroyed),
3) number of own people lost,
4) percentage of land exploration,
5) number of own villager high,

6) amount of gold collected,
7) number of technology researched, and
8) the highest age/civilization reached.

Pre-Testing

A total of six participants was used for pre-testing of the learning materials, the written test, and the computer simulation game. It was originally planned that only five participants were going to be used for pre-testing (i.e., one participant for each treatment condition). The very first participant could not complete the goals of the computer game. Consequently, some parts of the computer simulation game had to be changed due to the difficulty of the game scenario. Therefore, the complete pre-testing results were from the five subsequent participants.

Pre-testing determined the amount of time to be given for the future participants going through the learning materials. Therefore, during the pre-testing, the four participants going through the learning materials (reading at their normal speed) were timed on completing the entire material once. The average time to complete the learning material was 25 minutes 13 seconds and the slowest time was 30 minutes 10 seconds. But, to make sure that participants will have enough time to read the training material, a time limit of 30 minutes was used as the learning time in the actual experiment.

In terms of the written test, multiple choice questions were used. The 12 questions were selected from variations of the interactive questions used during the learning material. The difference in the written test scores was very minimal, so a decision was made to change the multiple choice questions to short answer questions to reduce unintelligent guesses on the test. The short answer type test, as shown in Appendix B, had slight alterations and required participants to write down the answer in words rather than just circling choices.

Finally, a survey questionnaire was given to the pre-testing participants. Overall, they had positive experiences with both the learning material and the computer simulation game and thought that the learned knowledge was useful in completing their given goals.

RESULTS

The results and analyses are separated into three sections. The first section is concerned with the written test scores. The second section is concerned with the time to complete the computer simulation game. The final section is concerned with the survey questionnaire. All analyses in this study were conducted at alpha (α) level of 0.05.

Although the results and discussion of this study used $\alpha = 0.05$, the reader should be aware that "confidence in one's results is inherently a continuous concept, not an all-or-none concept embodied by the 'significance/non-significance' dichotomy" (Wickens, 1998). The readers should pay just as much attention to results other than the ones dichotomized as significant or non-significant and make their own decisions about the confidence and usefulness of the results in this study. Depending on the type of situation one is trying to apply the results to, trade-off between Type I error (i.e., a "miss") and Type II error (i.e., a "false alarm") should be carefully weighed.

Written Test

Since the control group did not receive any learning material, the test scores are available only for the other four treatment groups with varying levels of frequency and quality of interactive questions. The four groups were as follows: 1) Low Frequency - Low Quality (LF-LQ), 2) Low Frequency - High Quality (LF-HQ), 3) High Frequency - Low Quality (HF-LQ), and 4) High Frequency - High Quality (HF-HQ).

The experimental design for the written test scores was the 2 x 2 between-subjects design. An analysis of variance (ANOVA) was performed using the written test scores to determine the effect of Frequency and Quality of Interaction on these scores. Table 2 summarizes the results of this analysis.

Table 2. ANOVA Table of Written Test Score.

Source	DF	SS	MS	F	P
Frequency (F)	1	19.3	19.3	0.11	0.737
Quality (Q)	1	501.3	501.3	2.96	0.094
F x Q	1	719.1	719.1	4.25	0.047 *
Error (Subject/FQ)	36	6095.4	169.3		
Total	39	7335.1			

** Significant at a = 0.05*

No main effects were found to be significant. But, the interaction between Frequency and Quality was significant. To further determine which of the learning materials were significantly different from each other, post hoc analysis was performed. Post hoc analysis using Least Significance Difference (LSD) Test showed that the written test scores from the HF-HQ group was significantly higher than the HF-LQ group. Since this study in one of the first in its kind, the LSD Test was used to find as many significant effects as possible.

Figure 5 shows the average results from the written test.

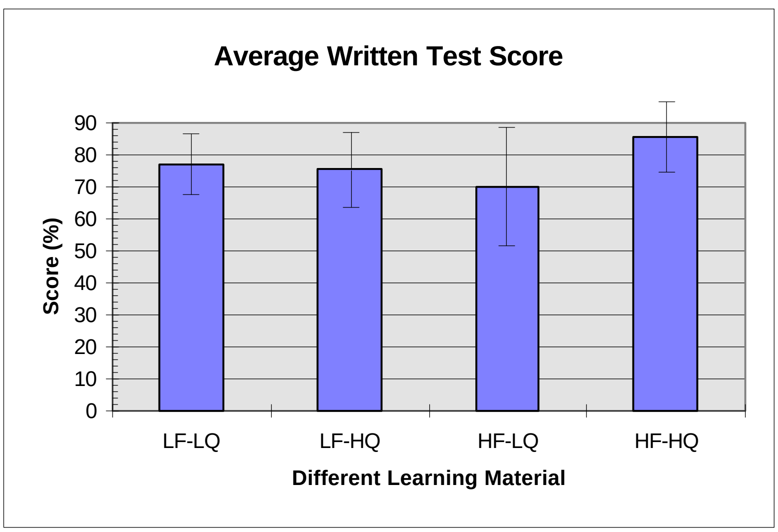

Figure 5. Average of Written Test Scores.

As can be seen from Figure 5, the learning materials with Low Frequency were not affected by the Quality of the interactions. But, High Quality of the interaction had a positive effect on the test scores with High Frequency materials

Computer Simulation Game

Although the main experimental design of this study is a 2 x 2 between-subjects design, when the additional control group is added, it can also be looked at as a one factor, five level, between-subjects design. That one factor is type of learning material with the control group being no learning material. An ANOVA was performed to examine if there was any significant difference in the computer game task completion time when the four learning materials were compared to the control group.

Table 3. ANOVA Table for Computer Game Completion Time (including the control group).

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	48384456	12096114	4.14	0.006 *
Error (Subject/L)	45	131322688	2918282		
Total	49	179707136			

** Significant at a = 0.05*

The main effect of Type of Learning Material was significant. Post hoc analysis using LSD Test showed that the LF-LQ group, the LF-HQ group, and the HF-HQ group all completed the game significantly faster than the control group. HF-LQ group was the only group that was not significantly different from the control group.

Figure 6 shows the average game completion time for the five treatment groups.

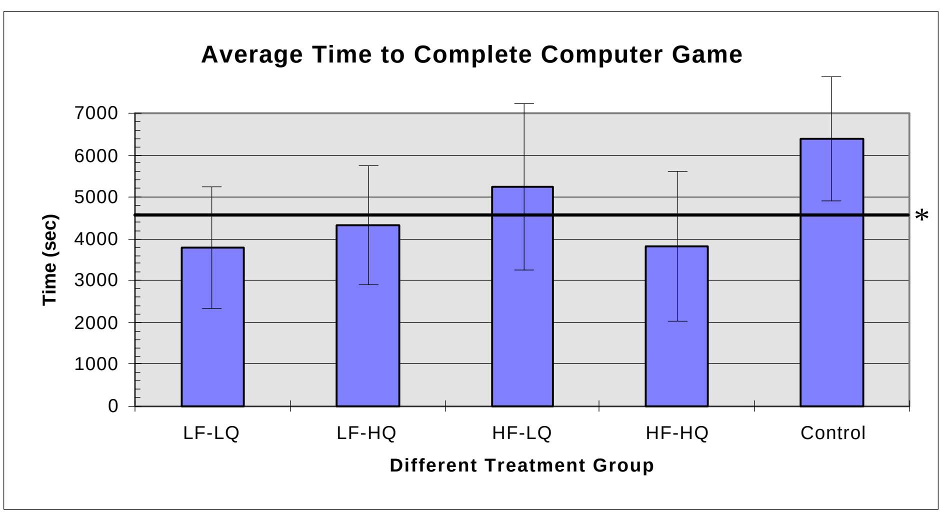

Figure 6. Average Computer Game Completion Time.

* *The bar indicates 30 minutes of learning time subtracted from the control group's time.*

Also, using the control group, transfer of training was measured with Percent Transfer and CTEF were calculated using equations (1) and (2), respectively. Average Percent Transfer and CTEF are summarized for each of the four training groups in Tables 5 and 6, respectively.

Table 4. Percent Transfer of Training.

LF-LQ	LF-HQ	HF-LQ	HF-HQ
40.5 %	32.2 %	17.8 %	40.0 %

Table 5. Cumulative Transfer Effectiveness Function (CTEF) Values.

LF-LQ	LF-HQ	HF-LQ	HF-HQ
1.44	1.14	0.63	1.42

CTEF > 1 = (learning time + game completion time) < control group game completion time

In order to determine if frequency and quality of interactive questions had any significant effect on the computer game completion time, ANOVA was performed as shown in Table 6. No main effect or interaction was significant.

Table 6. ANOVA Table for Game Completion Time (only for the 4 learning materials)

Source	DF	SS	MS	F	P
Frequency (F)	1	2256250	2256250	0.75	0.392
Quality (Q)	1	1968697	1968697	0.66	0.424
F x Q	1	9440066	9440066	3.14	0.085
Error (Subject/FQ)	36	108176360	3004899		
Total	39	121841368			

Additional supplemental game data were collected and are summarized in Table 7 and Figure 7. They were: 1) number of enemies killed, 2) number of razing (i.e., enemy buildings destroyed), 3) number of own people lost, 4) percentage of land exploration, 5) number of own villager high, 6) amount of gold collected, 7) number of technology researched, and 8) the highest age/civilization reached.

Table 7. Average of Additional Computer Game Data.

	# kills	# razing	# losses	% explore (in tens)	# villager high	amt. gold (in hundreds)	# technology researched	age*
LF-LQ	**13.6**	**2**	**10.4**	**7.81**	**16.4**	**10.18**	**9.6**	**1.4**
LF-HQ	**12.9**	**2**	**19.5**	**6.89**	**11.2**	**2.81**	**2.3**	**0.7**
HF-LQ	**14.6**	**2**	**16.3**	**8.52**	**16**	**11.65**	**10.2**	**1.3**
HF-HQ	**14.4**	**2**	**13.7**	**7.83**	**13.9**	**2.35**	**5.8**	**1.1**
Control	**12.5**	**2.1**	**23.3**	**6.98**	**11.2**	**4.07**	**5**	**1**

** For age (or civilization) level, 0 = Stone Age (the starting age), 1 = Tool Age, and 2 = Bronze Age. Higher the number, more advanced is the age (or civilization).*

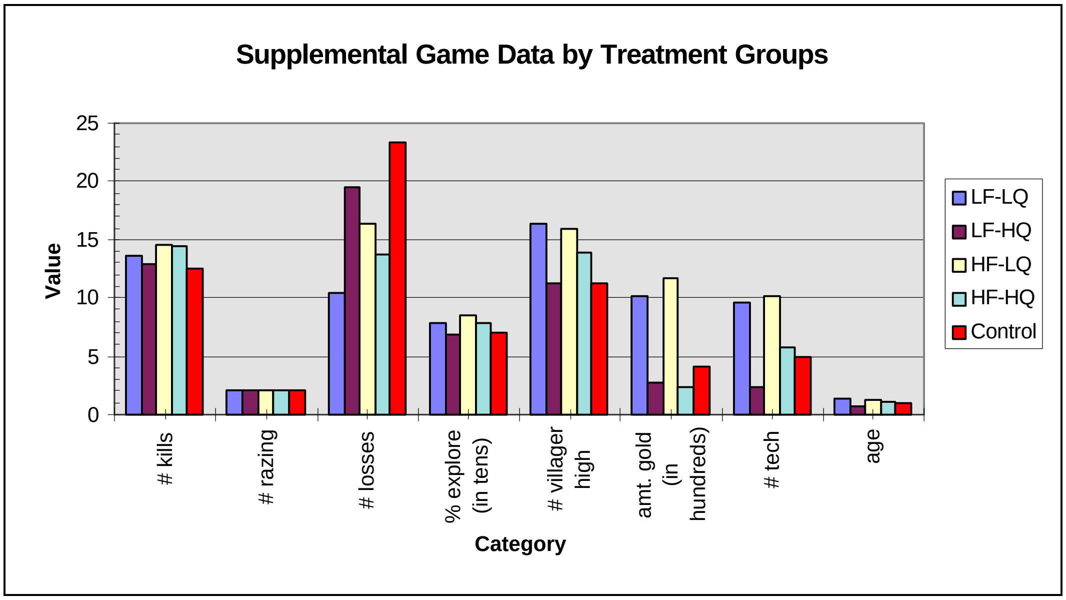

Figure 7. Additional Game Data Averages.

For each of the eight categories, an ANOVA was performed to determine any significant differences among the type of learning condition. ANOVA summary tables are shown in Appendix D. Three of the eight categories were found to be significant: number of own people lost ($p = 0.027$), amount of gold collected ($p = 0.005$), and number of technology researched ($p = 0.039$). Further post hoc analysis using the LSD Test was performed on the three significant categories.

For number of own people lost, the LF-LQ group vs. the LF-HQ group, the group vs. the LF-LQ control group, and the HF-HQ group vs. the control group were found to be significantly different. The LF-LQ group had significantly less number of own people lost than both the LF-HQ group and the control group. The HF-HQ group had significantly less number of own people lost than the control group.

For amount of gold collected, the LF-LQ group was significantly different from three groups (i.e., the HF-HQ group, the LF-HQ group, and the control group), and the HF-LQ group was significantly different from three groups (i.e., the HF-HQ group, the LF-HQ group, and the control group). Both the LF-LQ group and the HF-LQ group collected significantly more amount of gold than the HF-HQ group, the LF-HQ group, and the control group.

For number of technology researched, the LF-LQ group vs. the LF-HQ group and the HF-LQ group vs. the LF-HQ group were found to be significantly different. The LF-HQ group researched significantly fewer number of technology than both the LF-LQ group and the HF-LQ group.

Table 8 provides a listing of the correlations between the supplemental game data and computer game completion time. The correlation value between the written test scores and game completion time was found to be -0.408. None of the correlation values were found to be significant.

Table 8. Correlation of additional game data and time to complete game.

Number of kills	Time	**0.121**
Number of razing (buildings destroyed)	Time	**0.276**
Number of Losses	Time	**0.412**
% of exploration	Time	**0.145**
Number of villager high	Time	**-0.190**
Amount gold collected	Time	**0.057**
Number of tech researched	Time	**0.129**
Highest Age reached	Time	**0.124**

Survey

Average survey results are shown in Figure 8, separated by different treatment groups. Some of the values for the Control group are missing because those questions were not pertinent to them. The questions for the survey are listed in Table 9. See Appendix C for the exact survey given to the participants in this study.

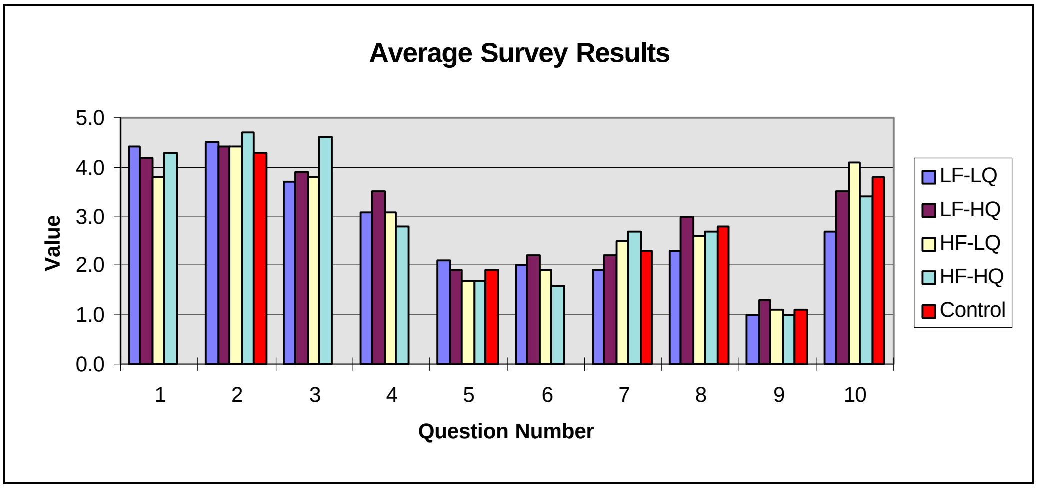

Figure 8. Average Survey Results

Table 9. Survey questions.

No	Question	Scale
1*	Your overall experience of the learning material was …	1 = Very Bad 5 = Very Good
2	Your overall experience of the computer simulation game was …	1 = Very Bad 5 = Very Good
3*	How helpful or meaningful were the questions asked during the learning session?	1= Not Very Helpful 5 = Very Helpful
4*	How often should the questions have been asked during the learning session?	1 = Much Less Frequently 5 = Much More Frequently
5	In your opinion, Web based instruction can be …	1 = Very Helpful 5 = Not Very Helpful
6*	How useful was the learning material in helping you to achieve the goals in the computer simulation games?	1 = Very Useful 5 = Not Very Useful
7	How would you rate yourself as a decision maker?	1 = Excellent 5 = Terrible
8	How fast do you usually make decisions?	1 = Very Fast 5 = Very Slow
9	How often do you use computers?	1 = At least once a day 5 = Hardly ever
10	How often do you play computer/video games?	1 = At least once a day 5 = Hardly ever

** These questions were not asked to the control group.*

An ANOVA was performed on each of the survey questions to assess significant differences among different treatment groups. The ANOVAs were performed for the survey questions because the questions are based on Likert scales and considered interval scale measures. The ANOVA summary tables are listed in Appendix E. Only one survey question showed significant difference and that was question number 3 as shown in Table 10.

Table 10. ANOVA Table for Survey Question 3.

Source	DF	SS	MS	F	P
Frequency (F)	1	1.6000	1.6000	2.74	0.106
Quality (Q)	1	2.5000	2.5000	4.29	0.046*
F x Q	1	0.9000	0.9000	1.54	0.222
Error (Subject/FQ)	36	21.0000	0.5833		
Total	39	26.0000			

In survey question number 3, the main effect (i.e., Quality) was found to be significant. Further post hoc analysis using LSD Test show that participants in the High Quality of Interaction circled significantly higher values than the Low Quality of Interaction participants. In other words, the participants in the High Quality of Interaction learning materials felt that the questions asked during the learning session were significantly more helpful than the Low Quality of Interaction participants.

To determine if any correlation between the survey questions and written test scores and computer game completion time existed, Pearson Correlation was obtained as shown in Table 11 and Table 12. The survey questions were found to be not significantly correlated with the written test scores and the computer game completion time.

Table 11. Correlation Between Survey Questions and Written Test Score.

Q1	Test Score	**0.415**
Q2	Test Score	**0.050**
Q3	Test Score	**0.097**
Q4	Test Score	**-0.245**
Q5	Test Score	**-0.134**
Q6	Test Score	**-0.106**
Q7	Test Score	**-0.074**
Q8	Test Score	**0.014**
Q9	Test Score	**-0.117**
Q10	Test Score	**-0.299**

Table 12. Correlation Between Survey Questions and Computer Game Completion Time.

Q1	Time	**-0.179**
Q2	Time	**-0.080**
Q3	Time	**0.273**
Q4	Time	**0.043**
Q5	Time	**-0.251**
Q6	Time	**-0.103**
Q7	Time	**0.360**
Q8	Time	**0.146**
Q9	Time	**0.135**
Q10	Time	**0.440**

Discussion

The goal of this study was to determine the effects of frequency and quality of interactive questions in a computer-based learning system. The two main dependent measures in this study were 1) written test score and 2) time to complete the computer game. By varying the levels of interactivity and including a control group, it was expected that some significant effects (at $\alpha = 0.05$) would occur on the dependent measures.

Effective Learning

One of the first things that needed to be considered was whether the learning materials were effective when compared to the control group. If the control group performed the same task faster than the groups receiving training or if any observed performance differences are minimal, then the learning can be considered ineffective and almost useless. The comparison of the four learning groups and the control group was done using the computer game completion time. Performance was measured on how fast one completed the game (i.e., faster the completion time, better the performance).

All four learning groups performed the task quicker than the control group as shown in Figure 6. This shows that the learning sessions were indeed effective. But, the degree of effectiveness also needed to be considered. Several methods were used to determine the degree of effectiveness of the learning materials compared to the control group.

Two methods (from Roscoe 1971, 1972) used to measure the transfer of training from learning to the computer game task were 1) Percent Transfer and 2) CTEF. Table 4 shows the Percent Transfer values for the four learning groups. If the Percent Transfer values are positive, then the groups with learning performed better (i.e., faster) than the group without the learning. The value also indicates the amount of time saved (e.g., 40 % means that the same task was performed in 40 % less time than the control group). Table 4 also shows that all the groups that learned in this study performed better than the control group. From the CTEF value, a score greater than 1 means that the training time plus the performance time is less than the time for the control group to complete the same task. As seen in Table 5, only the HF-LQ group had a CTEF value of less than one. The dark horizontal line shown in Figure 6 indicates the 30 minute learning time that the learned groups received, subtracted from the control group's time. In Figure 6, if the bars are below this dark line, that means the CTEF value is greater than 1. The only bar over the dark line among the trained groups was HF-LQ group. Again, similar to the written test scores, as shown in Figure 5, the HF-LQ group performed the worst. Using the CTEF, it was shown that three groups (i.e., LF-LQ, LF-HQ, and HF-HQ groups) had efficient transfer of learning and the HF-LQ group (although did perform better than the control group) was not as efficient in transferring learning to the task.

Another method used to measure the effectiveness of learning, compared to the control group, was the one way ANOVA. In this ANOVA, as shown in Table 3, it was found that Type of Learning Material was significant. Further post hoc analysis using the LSD Test showed that there is significant difference in computer game completion time for the LF-LQ group vs. the control group, the LF-HQ group vs. the control group, and the HF-HQ group vs. the control group. From observing Figure 6, this meant that the LF-LQ group, the LF-HQ group, and the HF-HQ group all performed the same task significantly faster than the control group. An interesting finding from the post hoc analysis here is that the three learned groups that had significant difference from the control group are the same three learning groups that had the CTEF value over 1.

These results show that when the computer game performance was used, the majority of the groups that went through the learning materials did perform their tasks significantly better and more efficiently when compared to the control group. The participants of the experiment actually learned from the training materials provided.

Multi-Dimensional Interactive Learning

The expected results from the two interactive learning components were that the High Frequency group and the High Quality group would perform better than their respective Low level groups. For the High Frequency group, since the learning materials were divided into smaller parts (i.e., less material to learn between each interactive questioning session), it was expected that those participants would more easily encode and store knowledge into their memory. For the High Quality group, since the interactive questioning sessions provided better feedback (e.g., addition of audio) and more options to the participants to encode and test their learning, it was expected that those participants would perform better.

What is surprising is that neither of those expected results occurred in the experiment. Neither frequency nor quality of interaction came out to be significant as main effects in the two major dependent measures. Unexpectedly, the interaction of the two factors, frequency and quality, was significant for the written test ($p = 0.047$). Although the same interaction of frequency and quality was not significant for the computer game completion time ($p = 0.085$), the same trend is present. This phenomenon maybe explained by accepting that interactive learning has many components and they must work together to make a learning system effective. Frequency and quality by themselves might not make an interactive learning session effective. Both components, at their correct levels, must work together to make an interactive learning effective. Borsook and Higginbotham-Wheat (1991) listed seven "ingredients" for interactivity; Milheim (1995-96) and Weller (1988) saw interactivity as having components of quantity and quality; Bork (1992) also listed several components of interactivity. In the written test, perhaps this is why the HF-LQ group scored the lowest and was significantly lower than the HF-HQ group. Since the HF-LQ group had a mixture of levels that was bad for the interactive questions, they scored the lowest. Likewise, since the HF-HQ group had a mixture of levels that was good for the interactive questions, they scored the highest.

One can see that the two Low Frequency groups scored similarly; whereas, the two High Frequency group scores differ much more as shown in Figure 5. This can be explained if the learning materials with Low Frequency were not affected by the Quality of the interactions, and the learning materials with High Frequency were affected by the Quality of the interactions. In the High Frequency case, High Quality had a positive effect on the written test scores and Low Quality had a negative effect on the test scores. One explanation of this effect maybe that the reinforcement of the learning materials in High Frequency requires High Quality to present and organize the knowledge given to the learners better. In other words; the demands of High Frequency interactions placed on the learners maybe remedied by High Quality.

Written Test vs. Performance in the Computer Game

Using different type of testing methods for the same learned knowledge, can be valuable. The effectiveness of the learning can be measured and seen in different application areas. In a case where traditional testing method is used to evaluate learning, the written test scores can be useful. Whereas, in a case where the learned knowledge has to be used in a real world setting, evaluating performance through a simulation such as the computer game in this study might be useful.

In observing the frequency and quality of interactive learning for either of the two cases in this study, the trend seems to be that the right mixture of components are needed for an effective learning. This does not necessarily mean that the best interactive component mixture used in the written test will be the same as the one that is best suited for the computer game.

To determine if the scores on the written test are any indication of the performance on the computer game completion time, a Pearson Correlation was found. The written test scores did not significantly correlate with performance on the game ($r = 0.41$). This means that just because people received a high score on the written test, does not mean that they will perform well when faced with the real world applying that knowledge. Also, many factors can attribute to the performance difference between the two testing methods. For example, a person might prefer taking a written test or a person who is familiar with the real world application does well applying the learned knowledge. Nevertheless, it is important to recognize where the learning material will be used so that it can be appropriately designed to be effective to that situation.

Additional Computer Game Data

To gain more insight into how and what type of strategy the participants in this study used to play the computer game, additional game data were obtained. The data are not necessarily reflective of the training effectiveness, since the learning materials did not specify any strategies relating to the eight categories of the data. Three categories (i.e., number of own people lost, amount of gold collected, and number of technology researched) were found to be significant. Out of those three categories, one in particular showed interesting post hoc analysis. For number of own people lost, the HF-HQ group and the LF-LQ group had significantly fewer losses than the control group. Both the HF-HQ group and the LF-LQ group performed significantly better than the control group. Therefore, out of the eight categories, number of own people lost seems to be the one metric that may indicate performance on the game (i.e., fewer the losses, better the performance). Also, common sense might suggest that if one loses a fewer number of people, they can complete the set goals more quickly.

Survey

Most of the participants were pleased with the learning materials and felt that the interactive questions were meaningful and that the learning material helped them perform better in the computer game. In terms of the frequency of the questions given during the learning, average survey value indicates that the participants thought that it was just right and seemed more or less indifferent. According to the survey, the average subject rated him/herself as an average decision maker. Almost all of the subjects used computers at least once daily and played computer/video games once biweekly. This is probably due to the fact that the subjects were college students in an environment where use of computers are encouraged; therefore, they were nearly at the same level in terms of familiarity with the technical equipment used in this experiment.

The participants in the High Quality of Interaction learning material felt that the questions asked during the learning session were significantly more helpful than the Low Quality of Interaction participants. That is probably due to the fact that the High Quality learning materials had more feedback as well as information on how to correct the mistakes made.

An interesting observation from the survey questions is that the average values in each question do not vary greatly among the different treatment groups; the average survey values were very similar among the five treatment groups. Despite the similar survey answers, the subjects in different treatment groups performed differently in their tasks. This could mean that although the people going through interactive learning materials might not consciously notice the difference, their performance can indicate otherwise and differ from one another.

Future Work

Several additional research issues need to be addressed based on the results of this study. First of all, more levels of the factors (i.e., frequency and quality) of interactivity should be studied. In this study, only two levels were used for each of the factors. The addition of the number of levels in those factors can show finer differences among the levels as well as a possible trend in those levels. By doing so, people will get a better understanding and more general idea of what levels of frequency and quality can exist and how they should be used in interactive learning materials.

More experimental factors of interactivity should be considered and used. Although only frequency and quality were used, there seems to be more than two dimensions in this concept of interactivity. Borsook and Higginbotham-Wheat (1991) listed seven "ingredients" (i.e. immediacy of response, non-sequential access of information, adaptability, feedback, options, bi-directional communication, and grain size) for interactivity; Milheim (1995-96) and Weller (1988) saw interactivity as having components of quantity and quality; Bork (1992) also listed several components of interactivity.

Individual differences also warrant consideration. Future researchers should consider factors such as spatial and verbal ability, reading comprehensibility, and display preference (e.g., paper vs. computer screen) for the instructions given to the participants. Some of the participants also commented that the individual difference in people who have played similar vs. dissimilar computer games as Age of Empires™ could have lead to misleading game completion time. One must remember not to collect data from too homogeneous of groups because then the generalizability of the results will be limited, and the results may not be practical. The "balancing act" must be carefully weighed.

Conclusion

The WWW is becoming ever more popular and socially accepted. In this phenomenon, education and training definitely has place in it. Schools like Virginia Polytechnic Institute and State University are already using the WWW to instruct students. Therefore, people must carefully consider how those instructions over a medium such as the WWW is being delivered and interacting with the users of those systems.

This study attempted to determine and define components of interactive learning that can be supported with empirical research results. When the written test score was used as the dependent measure, it was found that the interaction of the two factors was significant. It was found that one treatment group (i.e., the HF-HQ group) scored the best and with further post hoc analysis, found that the HF-HQ group scored significantly higher than the HF-LQ group. The two levels of Quality of Interaction had no effect on the Low Frequency of Interaction level. But in the High Frequency case, the High Quality level showed significantly higher written test score than the Low Quality level. Interactivity, therefore, is more than one dimensional. The right combination of interactivity must be determined in order to provide an effective instructional system.

The majority of the interactive learning groups performed significantly better than the control group on the computer game. Three out of four of the interactive learning groups were found to have good efficient transfer of learning from the computer-based instructions to the computer game task. Consequently, this study shows that the combination of the WWW and interactive learning and training hold great potential. More careful studies are needed for both the WWW and interactivity as teaching tools. Future studies must not only be theoretical, but emphasize empirical research to back-up and support those hypotheses and theories.

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APPENDIX A: INFORMED CONSENT FORM

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
of Investigative Projects

Title of Project: THE EFFECTS OF FREQUENCY OF INTERACTION AND QUALITY OF INTERACTION IN A WEB BASED LEARNING SYSTEM

Investigator: Jae Y. Kim

I. The Purpose of this Research/Project

There are many aspects of learning that can affect learners. One of these methods greatly praised today are interactive learning, especially on computers. But what does it mean for a computer instruction to be interactive? The purpose of this study is to examine the frequency and quality of interaction for a Web based instruction to better define and understand what it means for a computer instruction to be interactive. This study will also look at how the different levels of frequency and quality of interaction in the learning materials affect performance when the learned information have to be used to make decisions.

II. Procedures

In this study, you will be asked to go through a learning program on the computer for a period of time less than thirty minutes. On the learning program, you will be asked to follow directions on the computer screen. All you have to do is follow those instructions using the computer mouse provided. After the set time is up, the investigator will ask you to stop looking at the learning material.

After you go through the learning, you will be asked to perform a task on the same computer. Again, the directions and the objectives of the task will be provided for you on the computer screen. After the entire experiment is finished, you will be asked to fill out a questionnaire. The entire process will take approximately two hours.

III. Risks

There will be no risks associated with this study other than those encountered using a personal computer.

IV. Benefits of this Project

There are no direct benefits to you from this research. No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

The data gathered in this experiment will be treated with confidentiality. Your name will not appear on any collected data. Only a subject number will be used to collect data. You have the right to see your data and withdraw them from the study if you so desire.

VI. Compensation

You will be paid $5 per hour for the time you spend in this experiment. If you do not work in whole hour increments, you will be given an additional dollar for every twelve minutes.

VII. Freedom to Withdraw

You should know that at any time you are free to withdraw from participation in this research program without penalty. No one will try to make you continue if you do not want to continue, and you will be paid in full for the amount of time you participated.

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 have the following responsibilities:

(1) I should not volunteer for participation in this research if I have ever used the computer program called The Age of Empires™ by Microsoft.

(2) After completing this study, I will not discuss my experiences with any other individual for a period of one month. This will ensure that everyone will begin the study with the same level of knowledge and expectations.

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. I agree to abide by the rules of this project.

______________________________	______________________________
Signature	Date

Should I have any questions about this research or its conduct, I may contact:

Jae Y. Kim Principal Investigator	557-0776
Dr. Robert C. Williges Faculty Advisor	231-6270
Tom Hurd Chair, IRB, Research Division	231-5281

APPENDIX B: WRITTEN TEST

1. Name 3 Screen Components.

2. In which building can you create villagers and advance to the next age?

3. What are 2 things that can be done at a Granary?

4. What is one advantage of using a Scout?

5. List the 3 ages/civilizations in order from most to least advanced.

   Most =
   Mid. =
   Least =

6. What are the 4 resources that can be collected by villagers?

7. In which building can you create an Axeman?

8. What do the red dots on the Overview Map represent?

9. What can you do at a Market?

10. How many houses do you need to accommodate a population of 41?

11. How much food is needed to create 3 villagers?

12. How can you speed up the process of building?

APPENDIX C: SURVEY QUESTIONNAIRE

Thank you for participating in this study. Finally, I would like to ask you to fill out this questionnaire. Please circle only one choice for each question.

1. Your overall experience of the learning material was …

(1)	(2)	(3)	(4)	(5)
Very Bad	Bad	Average	Good	Very Good

2. Your overall experience of the computer simulation game was …

(1)	(2)	(3)	(4)	(5)
Very Bad	Bad	Average	Good	Very Good

3. How helpful or meaningful were the questions asked during the learning session?

(1)	(2)	(3)	(4)	(5)
Not Very Helpful	Not Helpful	Average	Helpful	Very Helpful

4. How often should the questions have been asked during the learning session?

(1)	(2)	(3)	(4)	(5)
Much Less Frequently	Less Frequently	It Was Just Right	More Frequently	Much More Frequently

5. In your opinion, Web based instruction can be …

(1)	(2)	(3)	(4)	(5)
Very Helpful	Helpful	Neutral	Not Helpful	Not Very Helpful

6. How useful was the learning material in helping you to achieve the goals in the computer simulation games?

(1)	(2)	(3)	(4)	(5)
Very Useful	Useful	Average	Not Useful	Not Very Useful

7. How would you rate yourself as a decision maker?

(1)	(2)	(3)	(4)	(5)
Excellent	Good	Average	Poor	Terrible

8. How fast do you usually make decisions?

(1)	(2)	(3)	(4)	(5)
Very Fast	Fast	Average	Slow	Very Slow

9. How often do you use computers?

(1) At least once a day
(2) Every other day
(3) Once a week
(4) Once every two weeks
(5) Hardly ever

10. How often do you play computer/video games?

(1) At least once a day
(2) Every other day
(3) Once a week
(4) Once every two weeks
(5) Hardly ever

COMMENTS:

APPENDIX D: ADDITIONAL GAME DATA ANOVAS

Analysis of Variance for Number of Enemies Killed.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	33.400	8.350	1.23	0.310
Error (Subject/L)	45	304.600	6.769		
Total	49	338.000			

Analysis of Variance for Number of Razing.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	0.08000	0.02000	1.00	0.418
Error (Subject/L)	45	0.90000	0.02000		
Total	49	0.98000			

Analysis of Variance for Number of Own People Lost.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	1002.32	250.58	2.99	**0.029***
Error (Subject/L)	45	3777.20	83.94		
Total	49	4779.52			

Analysis of Variance for Percentage of Land Exploration.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	1831.7	457.9	1.12	0.359
Error (Subject/L)	45	18413.1	409.2		
Total	49	20244.8			

Analysis of Variance for Number of Own Villager High.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	251.12	62.78	2.07	0.101
Error (Subject/L)	45	1364.50	30.32		
Total	49	1615.62			

Analysis of Variance for Amount of Gold Collected.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	7645232	1911308	4.22	**0.005***
Error (Subject/L)	45	20359028	452423		
Total	49	28004258			

Analysis of Variance for Number of Technology Researched.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	436.48	109.12	2.77	**0.039***
Error (Subject/L)	45	1775.70	39.46		
Total	49	2212.18			

Analysis of Variance for The Highest Age/Civilization Reached.

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	3.0000	0.7500	1.57	0.199
Error (Subject/L)	45	21.5000	0.4778		
Total	49	24.5000			

APPENDIX E: SURVEY ANOVAS

Analysis of Variance for Question 1

Source	DF	SS	MS	F	P
Frequency (F)	1	0.6250	0.6250	1.43	0.239
Quality (Q)	1	0.2250	0.2250	0.52	0.477
F x Q	1	1.2250	1.2250	2.81	0.102
Error (Subject/FQ)	36	15.7000	0.4361		
Total	39	17.7750			

Analysis of Variance for Question 2

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	0.9200	0.2300	0.67	0.618
Error (Subject/L)	45	15.5000	0.3444		
Total	49	16.4200			

Analysis of Variance for Question 3

Source	DF	SS	MS	F	P
Frequency (F)	1	1.6000	1.6000	2.74	0.106
Quality (Q)	1	2.5000	2.5000	4.29	**0.046***
F x Q	1	0.9000	0.9000	1.54	0.222
Error (Subject/FQ)	36	21.0000	0.5833		
Total	39	26.0000			

Analysis of Variance for Question 4

Source	DF	SS	MS	F	P
Frequency (F)	1	1.2250	1.2250	3.71	0.062
Quality (Q)	1	0.0250	0.0250	0.08	0.785
F x Q	1	1.2250	1.2250	3.71	0.062
Error (Subject/FQ)	36	11.9000	0.3306		
Total	39	14.3750			

Analysis of Variance for Question 5

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	1.1200	0.2800	0.51	0.731
Error (Subject/L)	45	24.9000	0.5533		
Total	49	26.0200			

Analysis of Variance for Question 6

Source	DF	SS	MS	F	P
Frequency (F)	1	1.2250	1.2250	1.53	0.225
Quality (Q)	1	0.0250	0.0250	0.03	0.861
F x Q	1	0.6250	0.6250	0.78	0.383
Error (Subject/FQ)	36	28.9000	0.8028		
Total	39	30.7750			

Analysis of Variance for Question 7

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	3.6800	0.9200	2.16	0.089
Error (Subject/L)	45	19.2000	0.4267		
Total	49	22.8800			

Analysis of Variance for Question 8

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	2.6800	0.6700	0.79	0.538
Error (Subject/L)	45	38.2000	0.8489		
Total	49	40.8800			

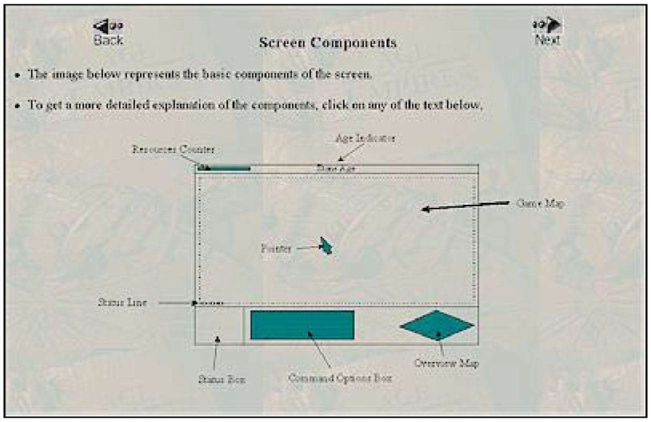
Analysis of Variance for Question 9

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	0.6000	0.1500	0.68	0.608
Error (Subject/L)	45	9.9000	0.2200		
Total	49	10.5000			

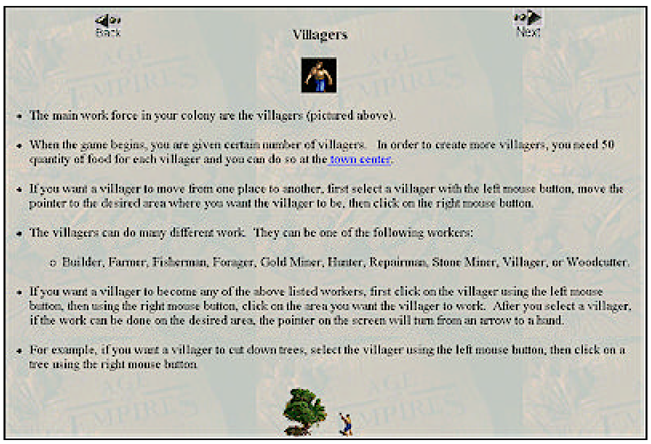
Analysis of Variance for Question 10

Source	DF	SS	MS	F	P
Type of Learning Material (L)	4	11.000	2.750	1.20	0.326
Error (Subject/L)	45	103.500	2.300		
Total	49	114.500			

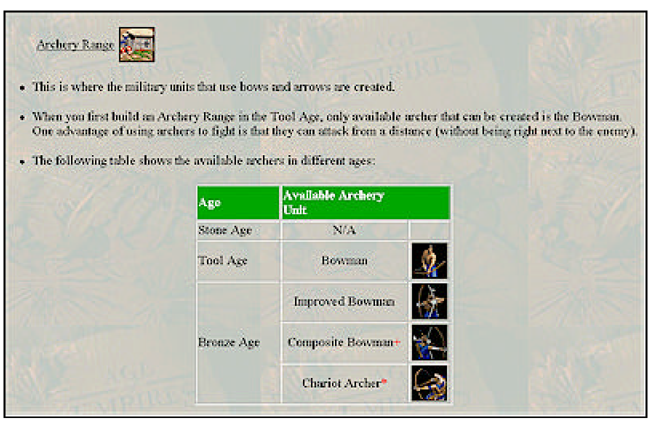
APPENDIX F: SAMPLE SCREEN DISPLAYS OF THE LEARNING MATERIAL



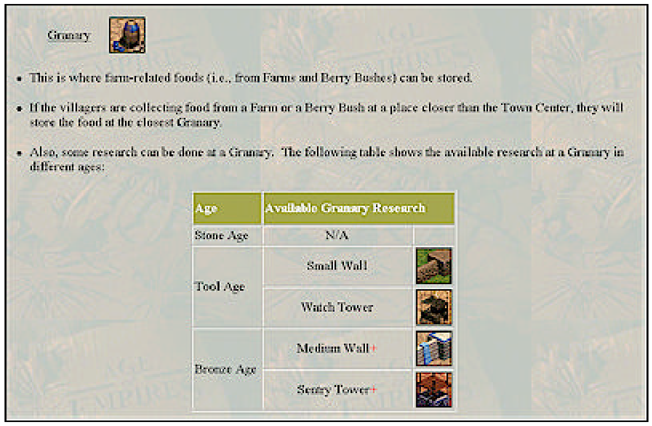
Display Explaining the Screen Components of the Computer Game



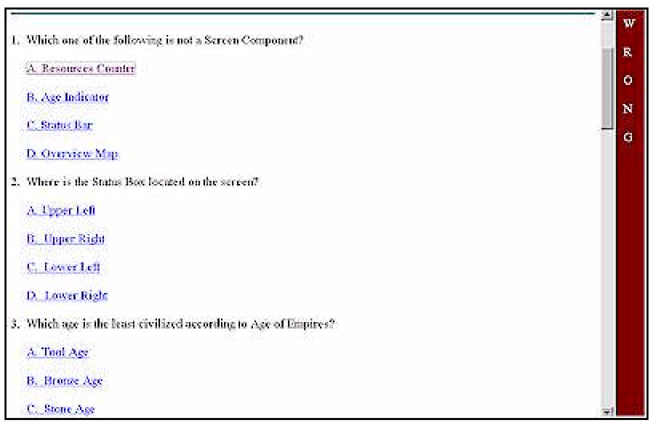
Display Explaining What the Villagers in the Computer Game Do



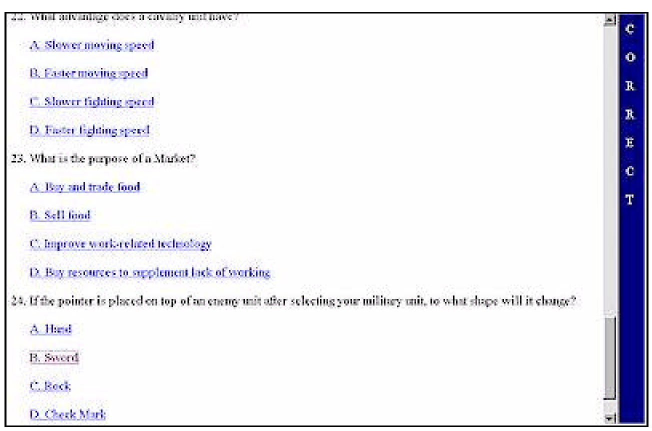
Display Describing What Can be Done at the Archery Range



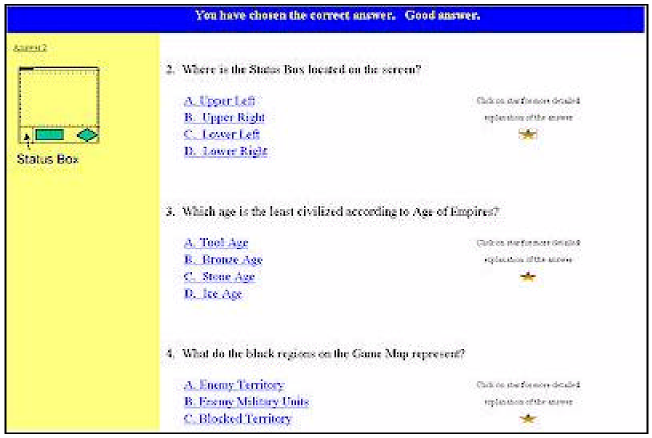
Display Describing What Can Be Done at the Granary



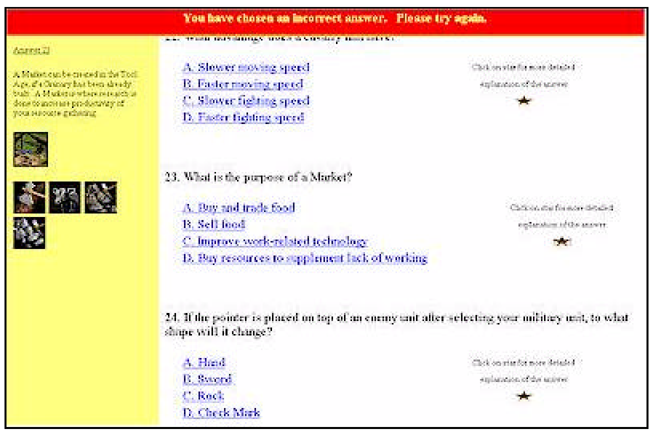
A Sample of Low Quality Interactive Questioning Session



A Sample of Low Quality Interactive Questioning Session



A Sample of High Quality Interactive Questioning Session



A Sample of High Quality Interactive Questioning Session

Screen Display of the Final Review Section

VITA

Jae Y. Kim attended Columbia University in New York City where he received a Bachelor of Science degree in Industrial Engineering. He worked as a private tutor teaching Math and English to students ranging from Elementary to High School. He also worked as a Sunday School teacher in his church. He attended Virginia Polytechnic Institute and State University to pursue a Master of Science degree in Industrial and Systems Engineering department, concentrating on Human Factors option. His interest in Human Factors is mainly in Human-Computer Interaction, but more generally, he wants to help design products to lessen the frustration and increase usability for the users. Also, his interest lies in using technology to better educate people. He is also a member of Alpha Pi Mu, which is the national industrial engineering honor society.