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Computer Based Gaming: The Effects On Motivation And Learning

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INTRODUCTION

The relationship between motivation and training is of central concern to both managers and organizational researchers. This relationship has a great impact on a multitude of factors that can affect the overall success of an institution. As pointed out by Steers and Porter (1987), employees must be able not only to perform their prescribed job duties dependably and effectively, but also to go beyond these minimal requirements and tackle work problems in inventive and original ways. Steers and Porter also noted that the advent of increasingly complex technology necessitates the implementation of various programs to ensure that workers are both willing and able to deal productively with these technological advances. They stated that many organizations are becoming increasingly aware of the importance of developing organizational members from a long-term perspective.

Many organizations are beginning to develop their employees as future resources. These organizations feel that employees will be more highly motivated and will perform better when job skills are enlarged and enriched through methods such as training, job rotation, and job re-design. It thus has become necessary for organizations to address the issue of motivation in the training of employees, because motivation can have a profound effect on the organization's bottom line.

The most frequently used traditional method of instruction in industrial organizations is on-the-job training (Goldstein, 1986). Although on-the-job training provides an opportunity to practice required job behaviors and may enhance transfer of training, the job environment may not necessarily be a good learning environment, particularly for the learning of complex information. For instance, the entire instructional process may be placed in the hands of an individual who is neither capable nor willing to instruct someone else on how to perform the job effectively. Furthermore, the learning environment may not be conducive to slowing down the work pace, evaluating trainee responses, or providing essential feedback to the trainee. One alternative or supplement to on-the-job training is the use of computer-based technologies. These alternative technologies can be designed to affect the individual's motivation toward participating in training, motivation in general, and consequently the effectiveness of the learning experience.

The diversity of applications of computer-aided instruction (CAI) has only been equaled by the diversity of designs for CAI systems. The use of computer technology for instruction has taken many forms, from simple electronic text presentation to prototype intelligent computer-aided instruction and intelligent tutoring systems. Some applications and designs have met with tremendous success (e.g., Wexley and Latham, 1981), while others have met with little or no acceptance by the users (Kearsley, 1985).

CAI can be more motivating and make learning more effective in a wide variety of settings, including industry and business, by using animated simulation to display

complex information and illustrate relationships that are abstract or difficult to visualize. While it has been shown that computers are good for teaching such things as concepts, facts, procedures, and problem solving, the motivation and attitude of the trainee must also be considered. Kearsley (1985) noted that automated instruction has not always been shown to be so successful from an organizational or institutional perspective. Specifically, the success of PLATO and TICCIT systems in colleges was dependent on the attitude of the instructors towards the system. The introduction of automated instruction also necessitates a focus more on individualized learning as opposed to classroom-based teaching where groups of students or employees do not necessarily enroll and graduate together. This directly affects the curriculum design requirements as well as management and organizational factors. Usability, screen design, degree of interaction, documentation, and error handling are a few of the factors that can affect the overall success of a computer-based training program.

Because well-designed systems have been so successful, CAI has profited as a viable technology for the classroom as well as a stand-alone device for communicating knowledge (Wenger, 1987). Wexley and Latham (1981) note that CAI has been increasingly used in work environments for teaching such things as administrative duties, technical information, perceptual-motor skills, and problem diagnosis. Furthermore, approximately 40% of major corporations are now using some form of computer-based training (Kearsley, 1985).

A substantial number of studies have indicated that CAI requires less time than traditional methods to teach the same amount of information (Goldstein, 1986; Wexley & Latham, 1981). For instance, the U.S. Army Signal Center and School found that, the use of CAI resulted in a 20% time savings. Additionally, when CAI was used in Navy training systems and Air Force electronics training, time savings ranged from 27% to 50%. This reduction in learning time can result in substantial cost savings for training (Kearsley, 1985). Studies also have shown that trainee reaction to CAI has been largely positive (Kulik & Kulik, 1986; Goldstein, 1986; Wexley & Latham, 1981). However, in contrast to positive trainee reaction to CAI, Kulik and Kulik (1986) found mixed results with respect to attitudes toward subject matter. They conducted a metaanalysis on the effectiveness of computer-based education in colleges. Out of 15 studies reported, only 6 studies showed that student attitudes were more positive with CAI as compared to more traditional methods of instruction. The remaining nine studies found that student attitudes, were more negative. There alto have been mixed results with respect to better performance, with the largest number of studies showing no significant differences between CAI and traditional instructional methods (Goldstein, 1986). As emphasized by Goldstein (1986), it is essential to investigate the quality of both the traditional method and new method when assessing the results of any particular instructional program.

Perhaps one reason that more studies have not found significant positive effects toward the material to be learned as a result of CAI is that most CAI programs are not adequately designed to engage the learning process. That is, something seems to be

lacking in these CAI programs which will motivate the student to sit down and interact with the instructional program. This may be especially true with more complex material. Previously, the student who is more motivated to interact with the instructional program will give more time and attention and consequently learn the material more effectively. One would also think that a positive by-product of using a CAI program that is motivating would be more positive attitudes toward the instructional material, which would carry over into the work situation. However, there is still no real systematic evidence for the effectiveness of CAI, although it is generally accepted as being more motivating.

The study presented here was designed to address the issue of motivation. Specifically, characteristics that are assumed to enhance motivation in CAI were investigated to determine if they had an effect on motivation, attitude, and learning. The following sections discuss those motivational characteristics.

The Problem Of Motivation

As pointed out by Katzell and Thompson (1990), work motivation (i.e., conditions and processes that account for the arousal, direction, magnitude, and maintenance of effort on-the-job) has become a hot topic for American society in recent years. This is due in a large part to the wavering productivity levels of organizations. Organizations are becoming increasingly concerned with creating work situations in which workers are better satisfied and hence more productive. Katzell and Thompson remark how there is no longer a limitless supply of individuals who are qualified for either unskilled entry-level positions or for more highly skilled jobs. Developing a pool of qualified individuals to meet a particular organization's needs, requires a training program that engages the learning process. In other words, the training program should be motivating enough for the individual to want to go through it and learn the material. By creating a training program that positively affects the motivation of the individual toward participating in training, a more motivated and productive employee in general should emerge.

Swenson & Anderson (1982) concluded that teaching techniques which incorporate positive motivation have been clearly shown to enhance learning. Since motivation has been found to be a critical aspect in learning, it should be considered in the design of CAI. Goldstein (1986) pointed out that one of the major advantages of CAI is its ability to provide reinforcement to the learner. Reinforcement refers to any event which follows a behavior and consequently increases the probability that the desired behavior will occur again (Swenson & Anderson, 1982). However, Goldstein also made note that one of the limitations of CAI is the fact that little has been done on the effects of a machine-oriented learning environment on such things 85 satisfaction and motivation.

A distinction is often made between extrinsic and intrinsic motivation. In the context of training, extrinsic motivation refers to learning that takes place dependent

upon the receipt of some external reward such as food, money, or social reinforcement for engaging in some desired activity (Malone, 1980). Intrinsic motivation, on the other hand, is learning that takes place in the absence of any external reward or punishment (Malone & Lepper, 1987a). It can be described as a need for self-competence, self-determination, and control in one's interaction with the environment (Zuckerman, Porac, Lathin, Smith, & Deci, 1978; Malone, 1980). When children are young, a large amount of intrinsically motivated learning takes place in the absence of any formal didactic instruction (Lepper & Chabay, 1985). Children learn through play because it is fun.

The issue is whether it is possible to make CAI learning fun for the student. The identification of learning environment characteristics which make it fun for the student has significant implications for the design of CAI programs. Lepper (1988) refers to a study that compared the types of study strategy students with different motivational orientations used in expository reading. Those students who learned the material simply for the sake of learning used strategies requiring deeper processing of information than those who simply wanted to do better than others. Lepper drew a parallel between this study and other studies that suggests an association between the use of deep-processing strategies and measures of subsequent learning and retention. The implications of this finding is that motivational factors should be considered when developing a CAI program.

Existing computer technology is capable of providing devices that can make learning fun and intrinsically motivating. And instructional programs can be designed in a way that will captivate the person's interest so that he or she is motivated to interact with the program and learn for the sake of learning-because it is fun, interesting, and rewarding in and of itself. Designing CAI that can engender intrinsically motivated learning is important in light of the fact that it has been found that extrinsic rewards may undermine activities that are highly intrinsically motivating (Malone, 1980; Kee & Worden, 1985). In essence, extrinsic rewards may actually degrade the quality of performance on certain tasks.

As pointed out by Malone and Lepper (1987b), the desire to design and implement intrinsically motivating learning situations stems from two related ideas. First, intrinsic motivation is a necessary prerequisite in a learning environment where participation is not mandatory. Second, the degree of intrinsic motivation experienced by a learner may affect what is learned and how effectively it is learned irrespective of the presence of extrinsic rewards. If learners are intrinsically motivated, they may not only spend more time and effort in learning, but they may also feel better about what they learn, subsequently transferring the training to a real work situation (Malone, 1980). Lepper (1985) has identified a number of CAI variables that have been shown to have a positive influence on intrinsic motivation. These critical variables are structure of the goals within an activity, relevance of the goals to the person, situational response, the contingency between actions and outcomes, and flexibility of choices provided to the learner (Lepper, 1985).

Games As A Solution

Recently developed computer and video games have been recognized for their intrinsic motivational appeal. As a result, interest has arisen within the instructional community about the application of this popular technique to instructional environments. Malone (1980) and Malone & Lepper (1987a,b) have identified a number of game characteristics which contribute to intrinsic motivation including fantasy, challenge, curiosity and novelty. Hence, the incorporation of game-like characteristics in learning environments may be a powerful tool to increase student motivation.

Fantasy

The influence of fantasy is a principle that can account for the popularity of computer games (Malone, 1980; 1983). The leap from computer games to computer-aided instruction was a short one. Subsequently, researchers have conducted numerous analyses of how fantasy might be applied to CAI as an effective motivator in learning.

Malone (1980) hypothesizes that fantasies in instructional environments can be used to harness preexisting emotional motivations (i.e., power, success, and wealth) in a manner which may increase interest in learning. Malone and Lepper (1987b) noted a few design principles to consider when planning a computer-based training program. First, fantasies should provide motivational goals that reinforce and complement instructional goals rather than compete with them. Second, feedback for failure in a fantasy context should not be made more interesting than feedback for success. Achievement of instructional goals in a fantasy-based exercise is of primary importance.

It appears that fantasy can provide an intrinsically motivating instructional environment and subsequently enhance learning by drawing the individual's attention to relevant material. Fantasy can also help to peak challenge and curiosity, as will be discussed later.

Challenge

The concept of challenge in particular has been emphasized by many theorists as an important element in intrinsic motivation (Malone, 1980). Terms such as effectance motivation, perceived competence, or self-efficacy are some of the concepts associated with challenges however, underlying these interpretations is the view that there is some optimal level of challenge for each individual (Malone, 1980; Malone & Lepper, 1987a,b).

Malone (1980) found that the single most important feature in computer games was the presence of a goal. He further stated that fantasy or practical goals are better

than goals of just using a skill. The presence of a goal, whether explicit or not, is an important aspect of challenge. Furthermore, Malone stated that short-term goals are better than long-term goals in increasing intrinsic motivation and task performance. Additionally, Malone and Lepper (1987a) proposed that performance goals should be personally relevant or meaningful to the person. Malone and Lepper suggested several ways to make goals meaningful to the individual. First, the functional utility of learning could be emphasized through instrumental relevance. That is, an association could be made between the proficiency in a subject and other skills the learner values or wants. Second, a particular fantasy or situational context that the learner finds intrinsically interesting could be built around the instructional material. Lastly, the material could be presented in a social context that engenders personal feelings such as cooperation, competition, or recognition.

Challenge is increased in instructional situations if achievement of the goal is not certain (Malone, 1980; Driskell & Dwyer, 1984; Fuller, 1985; Malone & Lepper, 1987a,b). Malone and Lepper (1987a,b) stated that varying difficulty level is one way to make a goal uncertain. Another way is to implement multiple levels of that goal. For example, similar goals could be made to differ with respect to difficulty or proximity. According to Malone and Lepper (1987b), multiple goals should be designed in accordance with instructional objectives, and learners should only feel skillful in the activity when they have achieved competence in those goals. Hidden or incomplete information is another way to make goals uncertain. Incomplete information seems to spark curiosity and challenge, which in turn motivates individuals to take some action. Randomness is yet another illustration of how to make goals uncertain. Baltra (1986) suggested that placing objects in different locations or altering the information of a map in adventure games are some examples of how to achieve randomness. With regard to designing a CAI program, Malone and Lepper (1987b) felt that randomness should not impede the sequencing of the lesson material or the presentation of feedback.

Related to the idea of having varying difficulty levels, Driskell and Dwyer (1984) stated that cumulative score keeping and an unlimited ceiling on performance can contribute to challenge. As pointed out by Meyers (1984), with an unlimited ceiling on performance, individuals can continue to improve their skills in an activity by employing various strategies, as they become increasingly proficient.

Malone and Lepper (1987a) stated that feedback in response to an individual's performance is an important factor in improving subsequent goals related to challenge. Feedback should be frequent, distinct, constructive, and inspiring (Malone, 1980; Baltra, 1986). As further stated by Malone and Lepper (1987a), feedback should be provided to the learner in a way to reduce damage to self-esteem. They additionally point out the importance of providing opportunities for success in the initial stages of the program, particularly to those individuals with low self-esteem and confidence. Also, before individuals advance to the next level of difficulty, they should feel a sense of personal accomplishment in the acquisition of skills. Moreover, individuals should be informed as to when they will be given more difficult exercises.

Thus, challenge is an intrinsically motivating characteristic that should be taken into consideration when designing a CAI program. The use of goals seems to play a major role in applying this concept.

Curiosity and Novelty

According to Malone (1980), the extent to which intrinsically motivating situations can continue to arouse an individual and then satisfy his or her curiosity is one of the most important features to be addressed in a learning environment.

Malone (1980) distinguished between the concept of sensory curiosity and that of cognitive curiosity. Sensory curiosity focuses on the properties of light, sound, or other sensory stimuli of an environment that draws the attention and interest of the individual. However, if these sensory stimuli are used only as decorative devices, they will only engender initial interest. Malone and Lepper (1987b) warn that the technical devices used to incite sensory curiosity should direct attention towards and not away from the instructional material to be learned.

Driskell and Dwyer (1984) stated that, in addition to the aforementioned features, fast pacing, operational complexity, novel environments, and game structures can be implemented in a program to help arouse curiosity. Furthermore, if repetition of information is required, it would be best to present different formats of presentation of information to maintain this optimal level of arousal (Dember & Earle, 1957). Computers can use audio and visual effects in teaching situations in much the same way that educational programs do by technically changing the image being viewed with regards to such things as angle viewed, color, size, flashing, etc. The use of sound and graphics can also be used to make fantasies more effective; by rewarding good performance, and thereby increasing goal relevance and game challenge; and by depicting the instructional material more effectively than can words or numbers.

Cognitive curiosity is concerned with making one's knowledge structures complete, consistent, and parsimonious. Since people are motivated to achieve completeness, consistency, and parsimony, one way to increase curiosity is to give only enough information to make present knowledge structures seem lacking with respect to the above. Malone and Lepper (1987a) also related the spreading interest theory to the concept of cognitive curiosity. The spreading interest theory basically suggested that individuals are intrigued with novel information that builds on some topic they are already interested in.

Factors that have been shown to incite curiosity includes the use of fantasies (Baltra, 1986), surprise related to previously held knowledge and expectations, and informational complexity. There appears to be some optimal level of informational complexity for any given person at any given time. Instructional environments should not be too difficult or too simple for the learner. A complex situation in which

expectations are sometimes met and sometimes not met seems to be the optimal level of informational complexity (Malone, 1980).

Moore and Anderson (1969) elaborated on four principles that can be used in designing educational environments that contribute to informational complexity. The first, the perspectives principle, implies that a situation should be approached from as many different perspectives as possible, thus making learning quicker and more effective. The second, the autoletic principle, tells us that learning should be intrinsically motivated. The third, the productive principle, suggests that instructional environments should be structured in such a way as to allow learners to make inferences about parts of the situation that have not been observed yet. The fourth, the personalization principle, states that the environment should be responsive to the learner by allowing the learner to investigate in an unrestrained manner, giving the learner immediate feedback, permitting self-pacing, encouraging discovery learning, and structuring the environment so that the learner can see the relationship between what has been discovered and various aspects of the world.

Malone (1980) proposed that the use of informative feedback is one way to enhance curiosity with regard to the design of an instructional environment. Feedback should be surprising by either using randomness or by disclosing things to the learner that seem surprising at first but that are nonetheless congruous with the overall environment. He further stated that it helps the learner to see how to adjust his or her knowledge structure in order to make it more complete, consistent, or parsimonious.

According to Orbach (1979), it is the construction of instructional exercises rather than the content that helps to create a sense of novelty in CAI. Orbach suggested that simulation games offer unique results for individual learners as a consequence of the decisions that were made. These unique results also add to unexpected change and surprise. Orbach (1979) further stated that a major advantage of using instructional simulation games for bringing about curious and perhaps creative behavior is that nonconformity is easily established and more acceptable in that situation.

In accordance with this research on novelty and curiosity, or stimulus-seeking behavior, it would appear that owe would strive to maintain novelty throughout the conduct of instruction so as to maintain an optimal level of motivation. The research conducted by Malone also supports the notion that novelty, curiosity, stimulus complexity, and surprisingness, all concepts evolving from Berlyne's work, play a major role in maintaining an intrinsically motivating environment for instruction.

Control

The amount of control an individual has is another variable that influences intrinsic motivation in a learning situation. The amount of control an individual has depends on the range of outcomes available in the learning situation and the

probability that each of the outcomes is contingent upon responses available to the individual (Malone & Lepper, 1987a,b). These researchers described an environment as being "empowering" if the outcomes are contingent upon the responses made by the learner. However, they stress that goals that are too complicated for the learner may impede the learner's sense of control and competence, which, in turn, can produce negative effects on intrinsic motivation.

Due to the very nature of using simulation as the medium of instruction for this research, which will be addressed in more detail later, all participants in the research study will feel a sense of control to some degree. Thus, the characteristic of control will not be discussed at length here and is not considered to be an independent variable in this research.

The Effectiveness Of Adding Game Characteristics

Does motivationally-enriched CAI produce more effective learning than CAI without these intrinsically motivating characteristics? The effectiveness of adding as stated by Malone and Lepper (1987a) and Lepper and Chabay (1985), educational philosophies differ in opinion with respect to how effective instructional computer games are as opposed to traditional drill-and-practice methods. On the one hand, opponents of instructional computer games believe that characteristics such as that of challenge, which are found in computer games, detract from and thus degrade learning. Additionally, some opponents feel that learning becomes less efficient in terms of the time it takes to master the material. On the other hand, some proponents believe that game-like characteristics promote better learning because attention becomes more focused, enabling deeper processing of the instructional content.

Another question of concern involves instructional material that is found initially to be uninteresting or unattractive. Does the addition of game-like characteristics enhance the motivational appeal of instructional material that is intrinsically uninteresting or unattractive? That is, can gaming increase the intrinsic appeal of the material both immediately following the learning situation and on subsequent occasions (Lepper & Hodell, 1989). There is little empirical evidence presented in the literature which address these questions. In particular, both questions need to be addressed with respect to adults, because most of the literature focuses on children.

Lepper and Hodell (1989) state that they have observed that some of these motivational embellishments can increase immediate interest in the activity. Their study compared the effects of two similar versions of a computer-based activity designed to teach students about Cartesian coordinates. One version provided problems and exercises in a fantasy context, while the other version did not. Lepper and Hodell found that those children who received the embellished version of the activity preferred to spend approximately 50% more time with that activity than did those children who received the unembellished version.

Recent research, according to Lepper and Hodell (1989), has found that these types of game characteristics can have positive effects on learning, even when the time spent on an activity is regulated so that differences in learning cannot simply be attributed to the amount of time spent on those activities found to be more intrinsically appealing. In three independent studies where the instructional content differed but where all incorporated some type of fantasy context, those children exposed to the motivationally embellished version experienced enhanced learning. Again, it is important to note that these studies focused on children.

Lepper and Hodell (1989) have further emphasized the importance of examining what types of long-term effects these game-like characteristics may have on subsequent intrinsic motivation and learning. Specifically, one should examine whether individuals will become more or less attentive or interested in the instructional content, which initially was embedded with game characteristics, on subsequent occasions. Will the instructional material increase or decrease in intrinsic appeal when the game features are removed? Lepper and Hodell (1989).found some evidence in support of the positive effects motivational enhancements can have in subsequent situations. Specifically, they found that those students who worked with the game-like version of an educational program designed to teach children about Cartesian coordinates reported more positive attitudes toward related aspects of the activity in a situation separate from the computer activity than those who did not receive the embellished version.

Lepper and Hodell (1989) also suggest that the benefits of using these intrinsically motivating characteristics can be seen with respect to subsequent learning or retention of the instructional material. Lepper and Hodell found that differences existed between conditions with respect to scores on paper-and-pencil achievement tests given 1-2 weeks following the experiment in those studies exhibiting an effect on learning as a result of incorporating game-like characteristics into the instruction. Furthermore, they found some evidence to indicate that differences in learning existed beyond the specific tasks inherent in the instructional activity. Additionally, they found that students performed better on tasks that built on the skills which they had already been taught.

These findings imply that incorporating game characteristics (i.e., challenge, fantasy, curiosity, and control) into instructional material may help to increase the motivational appeal for the activity and thereby enhance learning and retention (Lepper & Hodell, 1989). By incorporating game-like characteristics, it may be possible to increase positive attitudes toward the instructional content. However, the motivational goals must be congruent with the instructional goals of the activity if these motivationally-enriched environments are to bring about enhanced learning (Lepper & Malone, 1987b; Lepper & Hodell, 1989).

When designing an instructional environment, the needs and characteristics of the individuals undergoing training must be considered. Different individuals may find

different characteristics intrinsically rewarding. As pointed out by Lepper and Hodell (1989), these game characteristics or motivational variables may have the most effect on individuals who are least intrinsically motivated by the instructional content to begin with. The implications for such individuals is addressed in the current research.

Experimental Hypotheses

The experiment to be discussed is part of a research project at the Institute for Simulation and Training which is focused on the use of interactive animation and simulation to teach complex concepts. The purpose of this study was to examine whether or not the addition of game characteristics (e.g., the characteristics of fantasy, challenge, and curiosity) to an interactive simulation, would increase learning, as well as motivational appeal, of complex instructional material when compared to the interactive simulation without game-like characteristics.

An interactive simulation was designed to teach concepts in underwater acoustics. The lesson consisted of a series of exercises concerned with the environmental variables that affect the speed and direction of sound propagation underwater. The simulation enabled the subjects to explore the learning environment and discover the relationships affecting Underwater sound propagation. Since temperature is the foremost factor affecting the speed of sound, subjects were asked to manipulate temperature in the simulation to see its effect on underwater sound propagation. Textual explanations of the primary concepts to be learned were given at various points throughout the lesson. Graphic illustrations were also provided with the textual information to ensure clarity of information. The objective for all of the students was to apply each concept to the simulation, formulate and test hypotheses about the role each played in the. simulation, and use this information to guide continued interaction with the simulation.

Game characteristics thought to increase motivational appeal were embedded in the simulation. A fantasy goal of trying to locate the position of a hostile hidden submarine was present. In this game condition, the goal of the subjects was to narrow down the location of the hidden sub by manipulating the temperature profile. Varying the difficulty level in the game made the game environment uncertain, which increases challenge. Players received performance feedback in a number of ways so that they were able to determine whether they were getting closer to the game goal. Scoring also was implemented to let them know how well they were performing on the task. The subjects had as their goal to get as high a score as possible, which helped to create a challenging environment. To incorporate feelings of competition, subjects were able to view their score in comparison to the "top ten" scores achieved at that time. Randomness was incorporated into the game in order to make the game outcome more uncertain. Specifically, the "invisible" enemy sub was placed in various locations throughout the lesson. The subjects did not know where the enemy sub had been hidden over the different trials. Sound was also used to add excitement to the game.

When the subject had located the position of the sub, an explosion would sound and then the sub would sound like it was sinking.

It was hypothesized that, for those with an initial low disposition toward the material, the game format would focus attention and interest leading to increased motivational appeal and greater learning of the instructional content. In this setting, disposition refers to attitudes and propensity to think and act in a positive manner toward the instructional content (i.e., math and science related concepts). For those individuals already highly dispositioned toward the instructional content, it was expected that the game format would not produce a significant increase in learning or motivational appeal. These game characteristics may not add to the motivation to learn material that is already intrinsically appealing.

METHOD

Subjects

Forty students from the University of Central Florida participated in this research on a voluntary basis. Prospective students were given the opportunity to sign up for the experiment with the agreement that they would receive extra credit for their participation.

Materials

A Macintosh 11 with color monitor served as the training workstation. The CAI lesson was developed using Supercard (Appleton, 1989). The simulation and the game characteristics were developed using the C programming language. A description of the instructional simulation and game characteristics is provided in Appendix A.

Subjects were given a short 24-item questionnaire to measure their pretraining dispositions toward the instructional content (i.e., mathematical and scientific concepts). In order to check for internal consistency, a coefficient alpha reliability estimate was calculated for the pre-training questionnaire and found to be satisfactory ($R = .93$). A post-training questionnaire, comparable in form to the pre-training questionnaire, was designed to measure post-training disposition toward the instructional content. This questionnaire was also found to be internally consistent ($R = .91$). Both questionnaires were patterned after the Computer Anxiety Rating Scale (Heinssen, Glass, & Knight, 1987), a 20-item self-report inventory developed to measure an individual's level of computer anxiety. The Computer Anxiety Rating Scale was found to be reliable over a test-retest interval of four weeks ($r = .70$, $p < .0001$). In order to regulate for response set in both questionnaires, half of the items reflected anxiety-ridden statements about the instructional content (e. g. , I feel apprehensive about solving math and science related problems), and half of the items reflected non-anxiety statements (e.g., I am confident in my ability to learn new material related to

math and science). Participants were asked to indicate how much they agreed or with the statements by choosing the appropriate letter on the corresponding scale (A, B, C, D, or E), where A = strongly agreed and E = strongly disagreed, respectively. Responses were coded as follows: strongly agree = 3; slightly agree = 1; neither agree nor disagree 0; slightly disagree -1; and strongly disagree = -3. Scores range from 72 to -72 for both the pre-training and post-training questionnaires, representing a high level of disposition toward the material to a low level of disposition toward the material, respectively. Those individuals who scored above 24 on the pre-training disposition questionnaire were assumed to have had a high disposition toward the material. The difference between the scores on the post-training questionnaire and the pre-training questionnaire was determined in order to assess whether propensity toward the instructional material was affected as a result of the type of training received.

A 20-item user attitudes questionnaire was also developed in order to determine how subjects felt that the presentation of the material affected their ability as well as their motivation to learn the material. Two versions with similar content were developed, one for each of the experimental conditions, game and non-game. A coefficient alpha reliability estimate was computed and was found to be sufficient for both the game version (R = .94) and the non-game version (R = .95). The scores for the user attitudes questionnaire were determined in order to assess whether attitude toward the instructional material was affected as a result of the type of training received. The higher the score, the more positive the user attitudes.

Participants were given the Work and Family Orientation Questionnaire (Helmreich & Spence, 1978) in order to assess achievement motivation. This measure was to serve as a covariate for the data analysis. In addition, grade point average (GPA) scores were to serve as a covariate for general aptitude. In particular, three scales of the Work and Family Orientation Questionnaire were used in this study: Mastery (i.e., the desire for challenge), Work (i.e., the desire to perform well), and Competitiveness (i.e., the desire to do better than others in a competitive situation). Reliabilities, as expressed in alpha coefficients, were found to be satisfactory for all three scales, ranging from .61 to .76 for males and .62 to .72 for females. Participants were given 19 items, and they were to indicate on a five-point scale whether they agreed strongly or disagreed strongly with the self-descriptive statements given. Scores were obtained for each scale by summing the item scores. High scores indicate that the individual possessed more of that particular attribute.

Participants were given two short pretests before the start of the training program to assess their prior knowledge of the instructional material. In order to measure perceptual learning, subjects were given a 20-item multiple choice test. A KR20 reliability coefficient was calculated and revealed that the internal consistency of the test was satisfactory (R = .81). Specifically, subjects were given a particular sound speed profile and asked to select the sonar trace that would correspond to that particular profile. Subjects were scored in terms of the number of items answered correctly.

Additionally, subjects were given a pretest to ascertain their degree of conceptual understanding of the material. This 20-item test was comprised of fill-in-the-blank and multiple choice questions. A KR20 reliability coefficient was computed and proved that acceptable levels of internal consistency had been met ($R = .65$). Subjects were scored in terms of the number of items answered correctly.

Following completion of the training program, all participants were given the two aforementioned tests again in order to determine their degree of perceptual and conceptual learning. Both the perceptual and conceptual posttests were found to be reliable over a test-retest interval of two weeks ($r = .75$, $p < .0001$ and $r = .77$, $p < .0001$, respectively).

Procedure

Subjects were recruited by passing a sign-up sheet around several different classes. Before participating in the research, each subject first read and then signed a consent form developed in accordance with the guidelines established by the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

After the subjects signed the consent form, they were given the tools to measure disposition toward the instructional content and achievement motivation. Subjects were then given the perceptual and conceptual knowledge pretests.

Once this preliminary information was collected, subjects were randomly assigned to one of two conditions (i.e., the game version or the non-game version). A matched group design was employed such that an equal number of subjects found to have either a high or low disposition toward the instructional material was placed in each group based on the ratings found in the pre-training disposition questionnaire.

Subjects in both conditions were given a brief introduction as well as a set of standard instructions on the computer pertaining to the goals of the training before the start of the actual lesson. Specifically, the subjects were informed that the objective for the training was for them to understand how sound propagation paths were affected as a result of manipulations in the sound speed profile. Subjects were given a practice trial with which to become familiar with the controls and functions in the simulation. Subjects in the game version were also given the rules and goals of the game after they had finished reading the introductory material.

All subjects were required to spend 60-minutes learning the instructional content. After interacting with the program for 60 minutes, each subject was told that he or she could stop at any time within the next 15 minutes. A record was kept of how long each subject continued to interact with the instructional material. This was one way that motivation toward the material was measured.

Motivation was further measured by giving the post-training disposition questionnaire to the subjects in order to determine how their specific propensity toward the instructional content had been affected. Subjects were also given the user attitudes questionnaire that corresponded to the condition they had been assigned to. Once the subjects had completed the lesson in its entirety and taken the post-training questionnaires, they were given the two learning posttests. Subjects were then provided with feedback as to how they performed on the posttests if they desired; posttests were scored on the spot for those interested in finding out how well they did. Additionally, a retention score was collected on the learning posttests approximately two weeks later. Thirty-seven out of 40 retention scores were collected.

RESULTS

According to Arvey, Cole, Hazucha, and Hartanto (1985), the power of training evaluation designs is a function of several factors. Specifically, these researchers maintain that in order to obtain adequate power to detect true effects, the following factors must be considered: (1) the effect size, (2) the correlation between pretest and posttest measures, (3) the sample size, and (4) the type of design employed. Arvey et al. focused their efforts on the training evaluation designs of posttest-only, gain-score (i.e., posttest-pretest), and analysis of covariance (with pretest measures as the covariate). They stated that power is affected considerably by the correlation between pretest and posttest measures when either the sample size or effect size is low.

Based on the observations of Arvey et al., they developed several guidelines to follow when trying to select the evaluation design that provides the maximum power. Those guidelines relevant to this study will be discussed briefly: (1) analysis of covariance should be used when the total sample size is greater than 10 irrespective of pretest-posttest correlation; (2) the gain score design should be used when the sample size is less than 10 and the correlation between the pretest and the posttest is greater than .5; and (3) the posttest-only design should be used when the sample size is less than 10 and the correlation between the pretest and posttest is less than .5. These guidelines were considered in the selection of the most appropriate design to provide the maximum amount of power required to detect true effects for each level of analyses. All three types of training evaluation designs were performed, and it was found that the results substantiated the conclusions that Arvey and his associates made. Only those designs providing the most power were reported. GANOVA 4 (Brecht, Woodward, & Bonett, 1989), a statistical software package, was used to compute the power for each level of analyses; the following information was entered: (1) number of dependent variables, (2) number of between group factors, (3) number of levels for each factor, (4) number of subjects per cell, (5) alpha level, (6) means, (7) within cell variance, and (8) effect to be tested.

The two independent variables of interest that were manipulated in this study were game-like characteristics (e.g., the characteristics of fantasy, challenge, and curiosity) and disposition (i.e., the attitudes and propensity to think and act in a positive

manner toward the instructional content). There were several dependent variables obtained. Specifically, measures were taken upon completion of the training program to assess the following: (1) perceptual learning immediately following training, (2) conceptual learning immediately following training, (3) retention of perceptual learning approximately two weeks after training, (4) retention of conceptual learning approximately two weeks after training, (5) disposition toward the instructional material following training, (6) user attitudes toward the medium of instruction, and (7) time spent with the instructional material beyond one hour. In order to facilitate interpretation of the data, the variables have been grouped into three main categories. These categories include learning variables (i.e., perceptual and conceptual learning posttests and retention tests), disposition variables (i.e., post-training disposition measures), and attitude and motivation variables (i.e., attitude toward presentation of the instructional material and time spent beyond the required training time).

Learning Variables

Descriptive statistics were calculated for each of the learning variables for each group in the study (i.e., game, low dispositions game, high dispositions non-game, low dispositions non-game, high disposition) as well as across all of the groups. The means and standard deviations are reported in Table 1 and Table 2, respectively. Neither the covariates specified to be used in this study (i.e., GPA and Work and Family Orientation Questionnaire) nor the pretests were significantly correlated with the respective posttest measures (perceptual or conceptual); therefore, the analysis of covariance design was not used in the analysis of learning variables. Based on the recommendations made by Arvey et al.(1985), the posttest-only design was used, because the correlation between the pretest and posttest measures were found to be less than .5 (L= .13, perceptual; L= .07, conceptual). The power obtained from using this design was .92 and .97 respectively.

TABLE 1
MEANS AND STANDARD DEVIATIONS BY GROUP FOR PERCEPTUAL AND CONCEPTUAL POSTTESTS AND RETENTION TESTS

	GROUP			
LEARNING VARIABLE	GAME, LOW DISPOSITION	GAME, HIGH DISPOSITION	NON-GAME, LOW DISPOSITION	NON-GAME, HIGH DISPOSITION
Perceptual Posttest				
M	7.00	12.30	7.70	11.10
SD	4.42	4.37	2.83	4.01
Conceptual Posttest				
M	9.40	12.30	9.40	13.40
SD	3.37	2.06	2.17	3.31
Perceptual Retention				
M	5.50	11.90	5.50	11.11
SD	2.39	3.63	2.22	5.04
Conceptual Retention				
M	7.75	10.30	7.90	10.89
SD	4.13	2.58	2.42	2.85

NOTE: The values represent mean number of correctly answered questions.

TABLE 2
MEANS AND STANDARD DEVIATIONS ACROSS GROUPS FOR PERCEPTUAL AND CONCEPTUAL POSTTESTS AND RETENTION TESTS

LEARNING VARIABLE	M	SD
Perceptual Posttest	9.53	4.43
Conceptual Posttest	11.12	3.23
Perceptual Retention	8.59	4.55
Conceptual Retention	9.24	3.20

NOTE: The values represent mean number of correctly answered questions.

Perceptual Posttest

The main effect of type of instructional environment (i.e., game or non-game) was not found to be significant, $F(1, 36) = .04$, $p = .843$ (refer to Table 3). Thus, it can be concluded that the type of instructional environment did not produce a significant effect with respect to the number of questions answered correctly on the perceptual

posttest; that is, the two groups did not differ significantly as a result of the type of instructional environment to which they were exposed.

TABLE 3
SUMMARY OF THE ANALYSIS OF THE PERCEPTUAL POSTTEST

SOURCE	SS	df	MS	F
Instructional Environment (A)	.625	1	.625	.040
Level of Pretraining Disposition (B)	189.225	1	189.225	12.055*
A x B	9.025	1	9.025	.575
S/AB	565.100	36	15.697	
Total	763.975	39		

$p < .01$

The main effect of level of pre-training disposition toward the instructional material (i.e., low or high) was found to be significant, $F(1, 36) = 12.055$, $p = .001$ (refer to Table 3). therefore, it can be concluded that pre-training disposition produced a significant effect with respect to number of questions answered correctly on the perceptual posttest. On the average, the two groups did differ significantly as a result of their previous disposition toward math and science related concepts. As indicated by the group means, (see Figure 1 for a graphic representation of the means), the high disposition people answered the most items correctly on the perceptual posttest.

The interaction between instructional environment (i.e., game or non-game) and disposition (i.e., low or high) was not found to be significant, $F(1, 36) = .575$, $p = .453$ (refer to Table 3). Thus, type of instructional environment and prior disposition did not interact to influence the number of perceptual questions answered correctly.

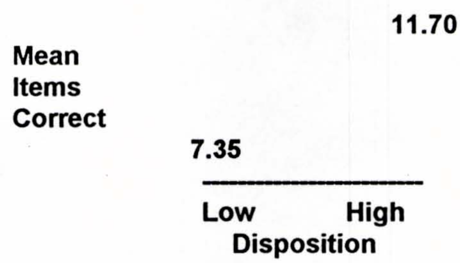

Figure 1. The Mean Number of Items Correctly Answered on the Perceptual Posttest as a Function of Disposition

Conceptual Posttest

The analysis of variance in the conceptual posttest data showed essentially the same pattern of results. The main effect of instructional environment (i.e., game or non-game) was not found to be significant, $F(1, 36) = .387$, $p = .538$ (refer to Table 4). The two groups did not differ significantly as a result of type of instructional environment.

The main effect of level of pre-training disposition toward the instructional material (i.e., low or high) was found to be significant, $F(1, 36) = 15.232$, $p < .0001$ (refer to Table 4). Therefore, the subject's pre-training disposition did produce a significant effect with respect to number of questions answered correctly on the conceptual posttest. On the average, the two groups did differ significantly as a result of their previous disposition toward math and science related concepts. As indicated by the group means, (see Figure 2 for a graphic representation of the means), the high disposition people answered the most items correctly on the conceptual posttest.

TABLE 4
SUMMARY OF THE ANALYSIS OF THE CONCEPTUAL POSTTEST

SOURCE	SS	df	MS	F
Instructional Environment (A)	3.025	1	3.025	.387
Level of Pre-training Disposition (8)	119.023	1	119.025	15.232*
A x B	3.025	1	3.025	.387
B/AB	281.3	36	7.814	
Total	406.375	39		

$p < .01$

The interaction between instructional environment (i.e., game or non-game) and disposition (i.e., low or high) was not found to be significant, $F(1, 36) = .387$, $p = .538$ (refer to Table 4). Thus, instructional environment and prior disposition did not interact to influence the number of conceptual questions answered correctly.

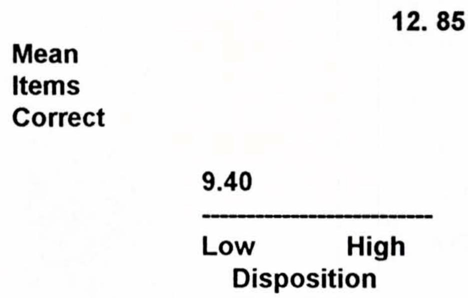

Figure 2. The Mean Number of Items Correctly Answered on the Conceptual Posttest as a Function of Disposition.

<u>Retention</u>

In analyzing retention, the type of evaluation design to be used depends upon the particular question asked. If one wants to know if there were any significant differences in absolute retention maintained after a two-week time interval, then the posttest-only design is appropriate. In this case, one would use only the retention scores. On the other hand, if one is interested in finding out whether there were any significant differences in percentage retained two weeks following training (i.e., differential forgetting), then the analysis of covariance design (with the posttest as the covariate) is applicable. Because the covariate was significantly correlated with the retention measure, and because both questions are of interest, both designs were performed. The power obtained from using the posttest-only design and the analysis of covariance design was 1.0 for each of them. The analysis of the retention data yielded the pattern of results as the analysis in the original tests. There were no main effects for instructional environment using either the perceptual or conceptual tests.

There was a significant ($p < .01$) main effect for level of pre-training disposition toward the instructional material (i.e., low or high) in all analyses (perceptual and conceptual: posttest and covariance design). There were no interactions found between instructional environment (i.e., game, or non-game) and disposition (i.e., low or high) for any of the retention data.

Disposition Variables

Descriptive statistics were calculated for pre-training disposition and post-training disposition for each group in the study (i.e., game, low disposition; game, high disposition; non-game, low disposition; non-game, high disposition) as well as across all of the group. The means and standard deviations are reported in Table 5 and Table 6, respectively.

TABLE 5
MEANS AND STANDARD DEVIATIONS BY GROUP FOR PRETRAINING AND POST-TRAINING DISPOSITION

	GROUP			
DISPOSITION VARIABLE	GAME, LOW DISPOSITION	GAME, HIGH DISPOSITION	NON-GAME, LOW DISPOSITION	NON-GAME, HIGH DISPOSITION
Pre-Training Disposition				
m	4.70	39.10	1.40	37.80
SD	14.02	10.56	14.07	11.22
Post-Training Disposition				
m	8.20	37.70	5.20	27.40
SD	18.59	12.03	21.97	12.60

TABLE 6
MEANS AND STANDARD DEVIATIONS ACROSS GROUPS FOR PRETRAINING AND POST-TRAINING DISPOSITION

DISPOSITION VARIABLE	M	SD
Pre-Training Disposition	20.75	21.65
Post-Training Disposition	19.63	21.15

Difference Between Post-Training Disposition and Pre-Training Disposition

Since one of the objectives of this study was to determine if one's prior disposition toward math and science related concepts would be subsequently affected as a result of the particular instructional environment, the difference between post-training disposition and pre-training disposition was explored. The analysis of covariance design was not used, because the specified covariates to be used in this study (i.e., GPA and Work and Family Orientation Questionnaire) were not significantly correlated with post-training disposition. The power obtained from using the gain score design was .51.

The main effect of instructional environment (i.e., game or non-game) was not found to be significant, $F(1, 36) = .869$, $p = .357$ (refer to Table 7). Thus, it can be concluded that the instructional environment did not produce a significant effect with respect to post-training disposition; that is, the two groups did not differ significantly as a result of instructional environment.

The main effect of level of pre-training disposition toward the instructional material at the start of training (i.e., low or high) was found to be significant, $F(1, 36) = 4.187$, $p = .048$ (refer to Table 7). Therefore, it can be concluded that the subject's disposition prior to training produced a significant effect with respect to the subject's disposition after training. On the average, the two groups did differ significantly as a result of their previous disposition toward math and science related concepts. As indicated by the group means, (see Figure 3 for a graphic representation of the means), those individuals with an initially high disposition toward the instructional material prior to training had a negative change in disposition following training; individuals with an initially low disposition had a positive change in disposition following training. The difference between the two difference scores was significant.

TABLE 7
SUMMARY OF THE ANALYSIS OF THE DIFFERENCE BETWEEN POST-TRAINING DISPOSITION AND PRE-TRAINING DISPOSITION

SOURCE	SS	df	MS	F
Instructional Environment (A)	189.225	1	189.225	.869
Level of Pre-training Disposition (B)	912.025	1	912.025	4.187*
A x B	216.225	1	216.225	.993
B/AB	7840.900	3	6217.803	
Total	9158.375	39		

$p < .05$

Difference Between Post-Training and Pre-Training Disposition

-5.90 **3.65**

Low High
Disposition

Figure 3. The Difference Between Post-Training and Pre-Training Disposition as a Function of Disposition.

The interaction between instructional environment (i.e., game or non-game) and disposition (i.e., low or high) was not found to be significant, $F(1, 36) = .993$, $p = .326$ (refer to Table 7). Thus, instructional environment and prior disposition did not interact to influence post-training disposition toward math and science related concepts.

Attitudes and Motivation Variables

Descriptive statistics were calculated for user attitudes toward the instructional medium and time spent in the lesson beyond one hour for each group in the study (i.e., game, low disposition; game, high disposition; non-game, low disposition; non-game, high disposition) as well as across all of the groups. The means and standard deviations are reported in Table 8 and Table 9, respectively.

TABLE 8
MEANS AND STANDARD DEVIATIONS BY GROUP FOR USER ATTITUDES AND TIME SPENT IN THE LESSON BEYOND ONE HOUR

	GROUP			
ATTITUDE AND MOTIVATION VARIABLE	GAME, LOW DISPOSITION	GAME, HIGH DISPOSITION	NON-GAME, LOW DISPOSITION	NON-GAME, HIGH DISPOSITION
User Attitudes				
m	19.40	36.90	13.10	18.50
SD	24.59	15.42	19.39	10.19
Time Beyond One Hour				
m	12.50	15.00	.60	1.50
SD	4.86	.00	1.07	2.42

NOTE: Time values are expressed in minutes.

TABLE 9
MEANS AND STANDARD DEVIATIONS ACROSS GROUPS FOR USER ATTITUDES AND TIME SPENT IN THE LESSON BEYOND ONE HOUR

ATTITUDE AND MOTIVATION VARIABLE	M	SD
User Attitude	21.97	19.68
Time Beyond One Hour	7.40	7.02

NOTE: Time values are expressed in minutes.

User-Attitudes

The user attitudes questionnaire assessed how well subjects felt that the instructional environment they received contributed to learning as well as to motivation. The higher the score, the more favorable the attitude toward the particular type of instructional environment received (i.e., game or non-game). The analysis of covariance design was not used, because the specified covariates to be used in this study (i.e., GPA and Work and Family Orientation Questionnaire) were not significantly correlated with user attitudes. The power obtained from only using user attitude scores was .49.

The main effect of instructional environment (i.e., game or non-game) was found to be significant, $F(1, 36) = 4.615$, $p = .039$ (refer to Table 10). Thus, it can be concluded that the instructional environment received did produce a significant effect with respect to user attitudes; that is, the two groups did differ significantly as a result of instructional environment. As indicated by the group means, (see Figure 4 for a graphic representation of the means), those individuals who received the training program with game-like characteristics found the instructional environment significantly more favorable than those who received the training program without the game-like characteristics.

TABLE 10
SUMMARY OF THE ANALYSIS OF USER ATTITUDES TOWARD THE MEDIUM OF INSTRUCTION

SOURCE	SS	df	MS	F
Instructional Environment (A)	1,525,225	1	1,525,225	4.615*
Level of Pre-training Disposition (B)	1,311,025	1	1,311,025	3.967*
A x B	366,025	1	366,025	1.107
B/AB	11,890.700	36	330,519	
Total	15,100.975	39		

$p < .05$

28.15

User
Attitude
Scores

15.80

Non-Game Instructional   Game Environment

Figure 4. The Mean User Attitude Score as a Function of Instructional Environment.

The main effect of level of pre-training disposition toward the instructional material (i.e., low or high) was found to be significant, $F(1, 36) = 3.967$, $p = .05$ (refer to Table 10). Therefore, it can be concluded that the subject's disposition prior to training produced a significant effect with respect to the subject's attitudes regarding the instructional environment. On the average, the two groups did differ significantly as a result of their previous disposition toward math and science related concepts. As indicated by the group means, (see Figure 5 for a graphic representation of the means), those people with an initially high disposition toward the instructional material prior to training found the instructional environment to be significantly more favorable than did those with an initially low pre-training disposition.

27.70

User
Attitude
Scores

16.25

Low   High
Disposition

Figure 5. The Mean User Attitude Score as a Function of Disposition.

The interaction between instructional environment (i.e., game or non-game) and disposition (i.e., low or high) was not found to be significant, $F(1, 36) = 1.107$, $p = .30$ (refer to Table 10). Thus, instructional environment and prior disposition did not interact to influence user attitudes toward the instructional environment.

Time

Time spent in the lesson beyond one hour was used an indication of how motivated the subjects were. Subjects were given the opportunity to continue in the training program for up to 15 minutes past the required one-hour training time. It was assumed that the longer the subject continued in the lesson, the more motivated he or she was. The analysis of covariance design was not used, because the specified covariates to be used in this study (i.e., GPA and Work and Family Orientation Questionnaire) were not significantly correlated with time. The power obtained from using the measurement of time was 1.0.

The main effect of instructional environment (i.e., game or non-game) was found to be significant, $F(1, 36)$ a 210.837, $p < .0001$ (refer to Table 11). Thus, it can be concluded that the instructional environment did produce a significant effect with respect to time spent in the lesson beyond one hour; that is, the two groups did differ significantly as a result of instructional environment. As indicated by the group means, (see Figure 6 for a graphic representation of the means), those individuals who received the training program with game-like characteristics stayed in the lesson significantly longer than those who received the training program without the game-like characteristics.

TABLE 11
SUMMARY OF THE ANALYSIS OF TIME SPENT IN THE LESSON BEYOND THE REQUIRED ONE-HOUR TRAINING TIME

SOURCE	SS	df	MS	F
Instructional Environment (A)	1612.900	1	1612.900	210.837*
Level of Pre-training Disposition (B)	28.900	1	28.900	3.778
A x B	6.400	1	6.400	.837
B/AB	275.400	36	7.65	
Total	1923.600	39		

$p < .01$

13.75

Minutes Beyond Required Training Time

1.05

Non-Game Game
Instructional Environment

Figure 6. The Mean Number of Minutes Spent in the Lesson Beyond the Required Training Time as a Function of Instructional Environment.

The main effect of level of pre-training disposition toward the instructional material (i.e., low or high) was not found to be significant, $F(1, 36) = 3.778$, $p = .06$ (refer to Table-11). Therefore, it can be concluded that the subject's disposition prior to training did not produce a significant effect with respect to time spent in the lesson beyond the required training time. That is, on the average, the two groups did not differ significantly as a result of their previous disposition toward math and science related concepts.

The interaction between instructional environment (i.e., game or non-game) and disposition (i.e., low or high) was not found to be significant, $F(1, 36) = .837$, $p = .366$ (refer to Table 11). Thus, instructional environment and prior disposition did not interact to influence time spent in the lesson beyond the required training time.

DISCUSSION

Perceptual and Conceptual Learning

With respect to both perceptual and conceptual learning, the analysis of the data indicated that, on the average, the participants who interacted with the game format did not perform significantly different on the learning tests than did those who interacted with the basic simulation without any game-like characteristics. As alluded to previously, opponents of instructional computer games believe that characteristics (e.g., characteristics of challenge) found in computer games detract from and thus degrade learning (Malone & Lepper, 1987a; Lepper & Chabay, 1985). However, the results of this study indicated that the game neither directly enhanced nor detracted from learning. A well-designed game should be motivating and not distracting as long as the learning goals are congruent with the game goals. This finding remained true regardless of the participant's prior disposition toward the instructional material. However, the participant's prior disposition toward math and science related concepts did in fact produce a significant effect with respect to the number of questions answered correctly on the two learning tests. Specifically, those individuals who had a high disposition or preference toward the material answered the most items correctly on the perceptual and conceptual posttests. There was no significant interaction present. Additionally, in terms of both absolute learning over a two-week time interval and differential forgetting for both the perceptual and conceptual posttests, the same pattern of results were found. That is, prior disposition toward the material (i.e., high or low) affected how well the participant performed on the retention tests, irrespective of the instructional environment (i.e., game vs. non-game format). Again, those individuals who initially had a high preference for the material performed the best on both of the retention tests.

Based on the results of this study, it seems that in terms of actual learning gain, individual differences with respect to preference for the material play a key role, while learning formats (game or non-game) do not. Disposition could be considered to have both a motivational and a cognitive component (e.g., pre-existing knowledge of learning

strategies, etc.). This being the case, then one would expect the game to enhance learning through the motivational component. However, in this study, the game did not affect learning, but did affect motivation. Perhaps the strong cognitive component or learning strategies used by high disposition individuals in both game and non game conditions over-powered any additional positive effects the game may have had on learning. An individual who initially has a preference for the type of material to be learned may not be so easily intimidated in the learning situation, when the material to be learned is complex, as it was in this study. The strategy used by high disposition individuals may focus attention more directly on the learning goals, thus allowing deeper processing and assimilation of the instructional material, with enriched learning as a subsequent result. On the other hand, the individual with a low initial preference for the instructional material may not be equipped with the type of strategies necessary to learn the complex material easily. Thus, additional effort must be focused on learning "how to learn" that material, which is an extra burden that an individual predisposed to the material does not have to carry. This may be especially true as the material becomes more complex and foreign to an individual. Presumably, individuals who have a high disposition or preference for certain kinds of material have voluntarily exposed themselves to that type of material much more than has someone who lacks interest in it and has a greater reservoir of appropriate learning strategies to use.

Post-training Disposition

The analysis of the data indicated that, on the average, the instructional environment did not produce a significant effect with respect to a change in disposition. However, as before, the subject's disposition prior to training did indeed produce a significant effect with respect to a change in disposition after training, regardless of the type of instruction received (i.e., game vs. non-game). Specifically, those with a high pre-training disposition score towards math and science related concepts had a reduced post-training disposition score toward the instructional material, whereas those with a low pre-training disposition score had an increased post-training disposition score.

The pre-training disposition and post-training disposition measures were comparable but were not exactly the same. Both questionnaires had the same number of items, and each question focused on the same general concept. However, the pre-training disposition questionnaire focused on general math and science related concepts while the post-training disposition questionnaire focused specifically on the math and science related concepts presented in this study (i.e., underwater sound propagation). One explanation for the finding that those with a high pre-training disposition score had a reduced post-training disposition score while those with a low pre-training disposition score did not could be that they were somewhat less disposed to this particular material. Those with a low pre-training disposition score may have been somewhat more disposed to this type of material than they originally thought. In this study, it seems that the subject's disposition toward math and science remains relatively stable over the learning trial irrespective of instructional environment. Those

with a high pre-training disposition toward the material had only a slight decrease in their post-training disposition score while those with a low pre-training disposition toward the material had only a slight increase in their post-training disposition score. The pre-training and post-training disposition questionnaires toward math and science related concepts do seem to be tapping into individual preference toward the material, and the questionnaires were found to be internally consistent (R = .93 and R = .91, respectively).

It is important to note that this finding was based on one learning trial. This finding may be different over a series of learning trials. At this point, it is not clear if this finding was a case of regression toward the mean or if disposition would, in fact, continue to improve over the learning trials for those with an initial low disposition. This is an area for future research.

This study indicates that individual differences in disposition toward material may have a significant effect on learning and should have an effect on the design of the instructional environment. More research needs to be done to determine the precise nature of these effects.

Attitudes and Motivation Level

In terms of how well participants felt that the instructional environment contributed to learning as well as to motivation, both the instructional environment received (i.e., game vs. non-game) and pre-training disposition (i.e., low vs. high) significantly affected user attitudes. Specifically, those individuals who received the training program with game-like characteristics found the instructional environment significantly more favorable than did those who received the training program without the game-like characteristics. Additionally, those with a high pre-training disposition toward the instructional material had a significantly better attitude toward the instructional environment than did those with a low pre-training disposition, irrespective of whether the simulation was presented in a game format. However, there was no interaction between type of instructional environment and disposition on user attitudes. Thus, those individuals who received the training program with game-like characteristics felt that the training program helped them to focus more clearly on the learning goals and provided the motivation necessary to persevere in the face of complex and difficult material. Additionally, those individuals who were initially predisposed to the type of material presented in the study felt the same way as those who received the game version, irrespective of the type of instruction they received.

With respect to the amount of time participants opted to spend on the lesson beyond the required training time, the type of instruction received did produce a significant effect. Specifically, those individuals who received the training program with game-like characteristics stayed in the lesson significantly longer than did those who received the training program without the game-like characteristics. However, pre-training disposition did not produce a significant effect with respect to time spent in the

lesson beyond the required training time. There was no significant interaction between type of instruction and pre-training disposition. Thus, those individuals who received the training program with game-like characteristics were indeed more motivated to spend time in the lesson. One would think that the longer one was motivated to stay in the lesson, the better one would learn the material. In this study, due to the practical time constraints, individuals were only allowed to remain in the lesson for up to 15 minutes beyond the required one-hour training time. If the participants had been allowed to stay in the study as long as they desired, perhaps their learning scores would have better reflected this increase in motivation. This may have been especially true for those with a low pre-training disposition. As alluded to before with respect to the cognitive component of disposition, it may be that the low disposition people had more "learning to learn" to do. The beginning of the learning curve for the low pre-training disposition people may have been just started. These concepts were very complex and difficult to learn. An hour and 15 minutes may not have provided an adequate amount of time for everyone to learn the material effectively. Perhaps with a high motivational format, disposition would increase over trials and all individuals would eventually learn the material. Also, if the participants had been given the option to quit when they wanted to, the low disposition non-game people may have learned a lot less.

In general, people liked the game format better than the simulation. However, for those individuals with a high pre-training disposition, the simulation itself without game-like characteristics was just as useful for learning as the simulation with game characteristics. More positive attitudes toward the game may help people with a low pre-training disposition to stay engaged in the lesson. Since people liked the game format better, a training program developer might as well design a training program which implements game characteristics. However, it is important that the game goals of the training program be congruent with the learning goals if effective learning is to take place.

Concluding Remarks

When designing and implementing a CAI training program, organizations may want to consider employing game characteristics and features in order to enhance intrinsic motivation. Game characteristics do not detract from learning (even for complex material) when the game goals of the lesson are congruent with the learning goals. Adults also find the game characteristics of fantasy, challenge, and curiosity to be motivating. However, for complex material, enhancing the motivation of low pre-training disposition people is not enough to enhance learning--at least in a single exposure to the material. Additional training sessions may be needed for low pre-training disposition people to learn the strategies necessary to assimilate and understand the material. In essence, if an organization is going to invest the time and effort to develop a simulation for training purposes, the addition of game characteristics will increase the motivational appeal with minimal additional expense.

Further research needs to be performed to determine the effect of games on low disposition people over a number of learning trials. There has been very little empirical research on what types of motivational characteristics help to increase learning in CAI. It would be of interest to determine exactly which game features adults find motivating, and related research should focus on when and why certain motivational characteristics succeed or fail in a particular learning environment. Additionally, a question of importance that needs to be addressed is whether there is more positive transfer of training to the real world as a result of incorporating game characteristics into CAI. In closing, much more research is needed to determine how people and organizations can benefit from the application and implementation of these game characteristics in training.

APPENDIX A

Instructional Domain And Simulation

The CAI lesson consisted of a series of exercises concerned with the variables that affect the use of sound to detect targets (i.e., submarines) underwater. One of the most important characteristics affecting the transmission of sound is the variation in the medium due to environmental factors. The speed of sound in the ocean varies as a function of three environmental variables: temperature, pressure, and salinity of the water. Temperature is the foremost factor affecting the speed of sound, and it usually decreases with depth. The speed of sound decreases with a decrease in temperature. Temperature, compared to the other factors, has the greatest effect on the speed of sound. Pressure, which increases with depth, causes a slight increase in sound speed. Salinity is usually fairly constant, except around oceanic fronts and in areas where there are fresh and salt water layers. The temperature, pressure, and salinity of ocean water typically change continuously resulting in sound speed gradients, although sharper changes can occur resulting in sound speed layers.

An accurate illustration of the sound propagation can be given by a sound ray diagram. The sound ray will change in direction by bending around a region of slower sound speed; the rays will therefore appear as curves. In an iso-sound-speed condition, the rays are straight lines emanating from the source and continue with little or no change in angle. When sound speed decreases with depth, the rays bend downward; when sound speed increases with depth, the sound rays are refracted upwards. Often there are combinations of gradients which can result in various phenomena such as sound rays "splitting" or going in different directions at the border between layers, or the creation of sound channels and convergence zones. Combined with phenomena such as surface reflectance and bottom bounce, a large variation of possible propagation paths exists (see Friedan, 1985 for a complete discussion).

Therefore, depending on the sound speed structure of the ocean surrounding a sonar transmitter, the sound will propagate along paths that will pass through some areas and miss other areas. The areas that are missed are referred to as "shadow zones". These shadow zones afford a target submarine a means of escaping detection.

There were two learning objectives in the lesson. The first objective was to learn how different values of two factors (temperature and depth) relate to variations in the sound propagation path. The second objective was to learn the concepts and principles which causally relate temperature and depth to the sound propagation path. The environment in which the subjects learned the two objectives was a simulation which enabled them to explore the environment and discover the relationships. The screen was divided into two primary sections (see Figure 7). The section on the left side of the screen consisted of a graph that displayed a temperature/sound speed profile relating temperature to depth. The black line with the boxes represented the

temperature at each depth in the ocean and ranged from -5 to 33 degrees Celsius. Subjects were able to manipulate the temperature profile by clicking on one of the black square "control points" representing different oceanic layers and dragging it to the desired temperature or position on the graph. The speed of sound was also displayed on the profile and was depicted by a red line. The speed of sound in water ranges approximately between 14 to 16 kilohertz.

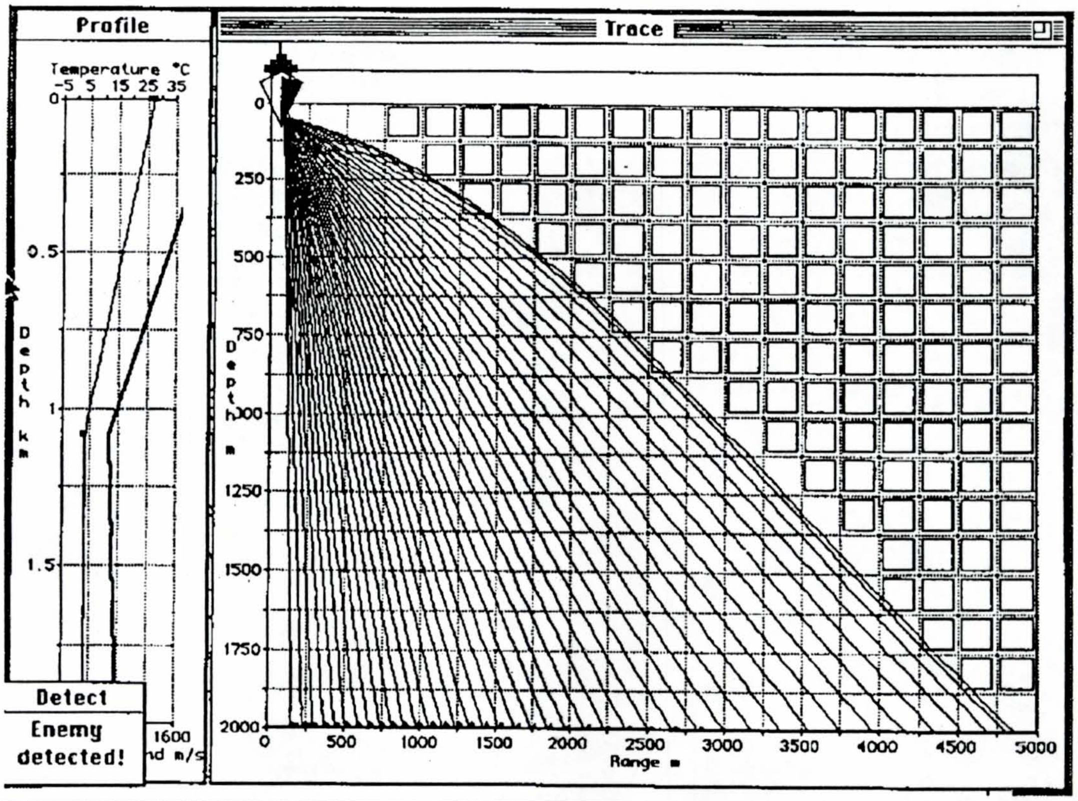

Figure 7. Temperature Profile and Trace

The section on the right side of the screen consisted of a grid of the "ocean" with a depth of 2000 meters and a range of 5000 meters. A sound source (i.e., surface ship) was located in the upper-left corner and could emit a sound signal that traveled through the ocean. The actual direction the sound signal took was a function (among other things) of the temperature of the ocean and the depth. The way in which sound behaves in the ocean is related to the difference in temperature over the ocean and the difference in depth. Bound was represented as ray paths.

A submarine was positioned strategically in various locations throughout the lesson (see Figure 7). In actuality, the sound rays would have traveled back to the source after intercepting the sub; however, this was not represented in the exercise. As the lesson progressed, the subjects were able to add control points to be manipulated in the temperature profile that corresponded to the ocean. The values of

temperature selected by the subjects were fed into a sound speed equation, which in turn served as input to the ray equations that drove the simulation.

Textual explanations of the primary concepts (such as refraction, critical angle, Halt rule, etc.) to be learned were given at various points throughout the lesson. Graphic illustrations were also provided with the textual information to ensure clarity of information. The objective for the student was to apply each concept to the simulation, formulate and test hypotheses about the role each concept played in the simulation, and use this information to guide interaction with the system.

Game Characteristics

As discussed previously, the game characteristics thought to increase intrinsic motivation were implemented in the instructional simulation. These game characteristics were fantasy, challenge, and curiosity. Thus, half of the subjects received just the simulation without any of the game characteristics incorporated into the lesson (i.e., the non-game version), and half of the subjects received the simulation with the game characteristics incorporated into the lesson (i.e., the game version). A discussion of the specific characteristics implemented in the game version is presented below.

Initially, before the subject started the actual game, he or she was given one practice trial in which to locate the hidden sub and practice implementing and observing the information found in the ten clues provided in the lesson. Subjects were given 15 chances to change the temperature profile for each trial. Their goal was to narrow down the range in which the sub was actually located by manipulating the temperature profile. This enabled them to learn how to manipulate the temperature profile and various related computer functions.

In the actual game, the submarine was invisible and represented an enemy sub. A fantasy goal of trying to locate the position of the hostile hidden submarine was present. In the non-game version, there was no fantasy goal present, just the goal of using a skill. There were two levels of difficulty implemented in the lesson. Within each level of difficulty, the subject was given three trials in which the hidden sub was strategically located in different areas of the ocean such that the difficulty level progressed throughout the game. They were allowed 15 chances to locate the hidden sub for each trial. The first level was relatively easy in that there was a wide "active" range around the sub so that it would not be too difficult for the subjects to detect and locate the sub. After the subject tried a particular temperature profile, he or she had the option of pinpointing the location of the enemy sub by clicking the cursor on that area of the screen one time. However, subjects were encouraged not to make random guesses and to only try to locate the hidden sub when a good portion of the screen had beer) narrowed down to a particular area. The second level was more difficult in that the subject had to directly pinpoint the exact location of the enemy sub.

Varying the difficulty level in the game made the game environment uncertain, which increases challenge. That is, the individual was neither certain to win nor certain to lose the game. The difficulty levels implemented in the game were spread out over the different scenarios that the subjects received, beginning with the easiest level and ending with the most difficult.

Players received performance feedback in a number of ways, so that they were able to determine whether they were getting closer to the game goal. First, a box would appear on the screen indicating whether the sub had been detected or found. No box appeared if the sub had not been detected. Once the sub had been found, it became visible to the subject so that he or she could confirm that the correct location was selected. Additionally, the sonar rays provided a form of performance feedback to the subjects, because they were able to use that information to make adjustments in their selections on the temperature profile. Scoring also was implemented to let them know how well they were performing on the task.

With respect to score-keeping, subjects had as their goal to get as high a score as possible. The concept of score-keeping lends itself very nicely to creating an environment which is challenging. During the game, the subjects proceeded through a series of trials (as many as time would allow). For each trial, the sub was hidden in a different location, and the subjects had 15 chances to vary the profile, trace the sound path, and then detect the sub. The scoring depended upon the number of attempts it took the subject to find the sub. Each subject began each trial with 10 points. The first five attempts were "free"; for each additional attempt, one point was subtracted from the total. For example, if the subject found the sub within the first five attempts, he or she got 10 points. If the subject took 15 attempts, then he or she got 0 points. In order to encourage the subject to explore all the possibilities early in the game, the subject's score was weighted. The raw score on the first trial was multiplied by one. The multiple increased by one for each trial, until the subject either ran out of time or reached the sixth trial. Therefore, finding the sub during the first five attempts was worth 10 x 1 = 10 points, whereas finding the sub during the first five attempts on the last trial was worth 10 x 6 = 60 points. The total possible number of points was 210. After each trial, subjects saw the following with respect to scoring the completed trial number, trial score, and cumulative score. To incorporate feelings of competition, subjects were able to view their score in comparison to the "top ten" scores achieved at that time after each trial. Subjects were also able to enter their score into the top ten list.

Randomness was incorporated into the game in order to make the game outcome more uncertain. The "invisible" enemy sub was placed in various locations throughout the lesson. In actuality, the subs were strategically placed in different areas of the ocean to make the game more complex. There was an appearance or feeling of randomness, because the subjects did not know where the enemy sub had been hidden over the different trials.

Sound was also used to add excitement to the game. When the subject had located the position of the sub, an explosion would sound and then the sub would sound like it was sinking.

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