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Accommodating the Needs of Field Dependent Learners in Simulation Gaming Environments

Ahmet Feyzi Satici
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To the Graduate Council:

I am submitting herewith a dissertation written by Ahmet Feyzi Satici entitled "Accommodating the Needs of Field Dependent Learners in Simulation Gaming Environments." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Edward L. Counts, Jr., Major Professor

We have read this dissertation and recommend its acceptance:

Dania Bilal, Jean A. Derco, John R. Ray

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Accepted for the Council:

Anne Mayhew

Vice Chancellor and Dean of Graduate Studies

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ACCOMMODATING THE NEEDS OF FIELD DEPENDENT LEARNERS IN SIMULATION GAMING ENVIRONMENTS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Ahmet Feyzi Satici
August 2006

DEDICATION

To my parents

Mustafa and Fatma SATICI

And to my family

Zubeyde and Enes SATICI

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This dissertation is the fruit of my educational journey in several universities. Without the guidance and assistance from many faculty, staff, and students at the University of Tennessee at Knoxville and other educational institutions, completing this dissertation would not have been possible.

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ABSTRACT

The field dependency and independency cognitive style affects the academic performance of students. It has been generally accepted that the needs of field dependent students could be accommodated in learning environments. The purpose of this study was to examine the effects of two instructional support features (model transparency and feedback) on the performance of field dependent and field independent students in a Web-based simulation environment.

In this study, there were two treatment groups. One group, consisting of 14 participants, received a black-box simulation (no model transparency) with no feedback (black-box + no feedback), and another group, consisting of 8 participants, received a glass-box simulation (with model transparency) with feedback feature (glass-box + feedback). The model transparency was provided in text-only format. The feedback was diagnostic and immediate. To assess the participants' cognitive style, the Group Embedded Figures Test (GEFT) was implemented. The participants' achievements were evaluated with a performance assessment method that showed the near-transfer skills.

The results of this study revealed that the simulation performance was similar for both the participants interacting with the glass-box simulation with feedback feature and the participants interacting with the black-box simulation with no feedback feature. There was no statistically significant correlation between participants' degree of field independency (GEFT scores) and their simulation performance. Finally, there was no interaction between the treatments and the cognitive style of participants.

Significant performance differences were reported in the literature for field dependent and field independent students in learning environments. The results of this study were contradictory to the literature review. Directions for future research are discussed.

TABLE OF CONTENTS

List of Tables

List of Figures

CHAPTER ONE

INTRODUCTION TO STUDY

Introduction

Individuals differ in many aspects. These differences make us unique and provide us with different life experiences. For individuals, “those differences affect the courses they take and succeed in, the careers they choose, and even the friends they select” (Jonassen & Grabowski, 1993, p. 16). Students’ age, gender, previous knowledge of the subject, intelligence, intrinsic and extrinsic motivation, and cognitive styles are some of these individual differences. Studies in individual differences constitute an important part of the educational research literature. Many educational theorists and researchers identify these differences and investigate their effects in various instructional materials and educational environments.

Cognitive style is defined as “an individual's preferred and habitual approach to organizing and representing information” (Riding & Rayner, 1998, p. 8). Every cognitive style dimension is a continuum between two extremes, “… an individual at one end of the continuum will be good at some tasks and poor at others, while for a person at the other extreme the situation will be the reverse.” (Riding & Mathias, 1991, p. 384) This bipolar aspect of cognitive style is the main distinction that differentiates cognitive styles from intelligence. While having higher intelligence is favorable in educational settings, neither extreme of a cognitive style dimension is more favorable than the other extreme.

Although change in one's cognitive style is possible over time (Luk, 1998a; Witkin, Moore, Goodenough, & Cox, 1977), the effects of cognitive styles are persistent and wide-ranging over time (Davis, 1991; Messick, 1993; Riding & Cheema, 1991; Witkin et al., 1977). Riding and Cheema (1991) identified more than 30 different cognitive style dimensions in the literature. One of the earliest identified of these dimensions was field dependence (FD) and field independence (FI).

The FD/FI cognitive style was determined and developed by Herman A. Witkin and his colleagues during the late 1940s. In their early research, Witkin and Ash studied the effects of visuals on individuals' perception of upright position (Witkin & Asch, 1948). Later, these studies evolved "from the narrow 'perception of the upright', to 'perceptual-analytic ability'" (Riding & Cheema, 1991, p. 197). The main differences between FD and FI individuals were explained by (Witkin et al., 1977) as:

> The person with a more field independent way of perceiving tends to experience his surroundings analytically, with objects experienced as discrete from their backgrounds. The person with a more field dependent way of perceiving tends to experience his surroundings in a relatively global fashion, passively conforming to the influence of the prevailing field or context. (p. 14)

FD/FI Cognitive Style and Academic Performance

The FD/FI cognitive style was questioned whether it is a cognitive style. According to Jonassen and Grabowski (1993), FD/FI was a cognitive control, placing FD/FI between cognitive styles and mental abilities. According to Zhang (2004), it was another measurement of intelligence. While the debate on this issue has been continuing, a relationship between the FD/FI cognitive style and academic achievement was accepted by many researchers. “Field dependent learners generally perform less well than field independent individuals in most instructional environments” (Hall, 2000, p. ii) except in some unintentional learning conditions (Witkin et al., 1977). Bishop-Clark (1992) reviewed the literature on the relationship between the FD/FI cognitive style and academic achievement in programming classes. A statistically significant positive relationship between the students’ degree of field independency and their success in programming classes was found. Other studies demonstrated similar results (Baker & Dwyer, 2005; Dwyer & Moore, 2001; Hall, 2000; Kush, 1996; Lin & Davidson, 1994; Luk, 1998b).

Accommodating the Needs of FD Students

According to Saracho (2003), FD and FI students have different approaches for processing and refining knowledge. FD students pay attention to external referents; FI students use internal referents. Organizing and synthesizing information is a problem for FD students; thus, they prefer learning environments that have been previously structured and synthesized for them. FI students are capable of organizing and synthesizing information; therefore, they can be successful in any environment. Some aspects of instructional materials and learning environments can be modified to provide FD students with appropriate structure (Dwyer & Moore, 2001). This idea is generally suggested in the literature despite opposing ideas (see Ikegulu & Ikegulu, 1999; Merrill, 2002). Angeli and Valanides (2004) suggested finding “the ways of achieving optimal cognitive coupling” by implementing various strategies in textual and visual material.

Various instructional strategies to accommodate the needs of FD students in various educational environments have been investigated. Different linking structures in Web-based materials (Ford & Chen, 2001), cooperative learning on computer-based instruction (Whyte, Knirk, Casey, & Willard, 1990-91), color-coding in written instructional materials (Dwyer & Moore, 1994, 2001), and feedback level in multimedia based instructions (Baker & Dwyer, 2005) were some of the instructional strategies found to be interacting with the FD/FI cognitive style. Implementing these strategies in instructional materials and educational environments accommodates the needs of FD students by providing matching conditions.

Problem Statement

Reiff (1996) states that FD individuals are more likely to face "'cognitive dissonance' or mismatch" than FI individuals in educational institutions. The importance of accommodating the needs of FD individuals in all instructional materials and educational environments is emphasized by various researchers (Dwyer & Moore, 2001; Witkin et al., 1977). However, an instructional strategy used for accommodating the needs of FD individuals in one educational environment might not accommodate the needs of FD individuals in other educational environments. In addition, not all instructional strategies used for accommodation can be implemented in all instructional materials and learning environments. For example, different linking structures used in multimedia and hypertext instructional materials are not possible to implement in paper-based instructional materials. Even when an implementation is possible, some features of instructional materials or educational environments might reduce the effectiveness of instructional strategies used for accommodation.

Recent advancements in instructional technologies provide us with newer opportunities; hence, many tools that were not accessible are now easier to reach and employ in the educational environments. Some of these tools are computer-based simulations and simulation-games. With new authoring and programming tools, it is easier to create and implement computer-based simulations and simulation games. These dynamic learning environments require students to create and test hypotheses. Unlike many other instructional materials, computer-based simulations and simulation-games provide experiential exercises (Gredler, 1996, 2004). These features differentiate computer-based simulations and simulation-games from other forms of computer-based instructional materials. Therefore, it is questionable to assume that the instructional strategies used for other computer-based instructional materials and learning environments to accommodate the needs of FD students will work with simulations and simulation-games.

The Purpose

The purpose of this study was to examine the effectiveness of two instructional strategies on the performance of students with various degrees of the FD/FI cognitive style in a computer-based simulation-game environment. The two strategies implemented were feedback and glass-box vs. black-box design. According to Alessi (2000b), glass-box simulations include “details of the underlying model that can be seen by the user (is transparent)" (p. 179) and black-box simulations are "those in which the underlying model is not seen (is opaque)" (p. 179). The results of the study contribute additional information regarding design and development of computer-based simulation-games, and their effects on students' performance. The results of the study also contribute additional information on the FD/FI cognitive style research. The study investigated whether the FD/FI cognitive style affects the performance of students in computer-based simulation-game environments, and whether the strategies implemented in this study provide a structure for FD students to achieve the same level as FI students.

Importance / Need for the Study

The existence of a relationship between the FD/FI cognitive style and academic achievement is accepted by many researchers. However, it is also supported by previous research that FD students can be as successful as FI students when special strategies and instructional support features are implemented in the development of instructional materials and learning environments. The compensatory matching of instructional strategies in instructional materials and learning environments improves learning performance (Ford & Chen, 2001; Park & Lee, 2004). Even though some authors discussed that studying with mismatching (or challenge match) environments provide students with an opportunity to overcome the weaknesses of their cognitive style, Reiff (1996) claimed that due to mismatching environments, FD students might be even labeled as "at-risk" students.

There are ample studies investigating the ways of accommodation of FD students' needs in computer-based instructional materials and learning environments. Computer-based simulations and simulation-games are parts of computer-based learning environments; however, simulations have unique characteristics. Due to these characteristics of computer-based simulations and simulation-games, the strategies implemented to accommodate the needs of FD students in other computer-based instructional materials cannot be directly implemented in these environments. Despite their widespread use in educational and training settings, there is not sufficient cognitive style research to support the implementation of instructional support features in simulation environments.

As stated by Gredler (2004), unlike many computer-based instructional materials, simulations provide students with a chance to deal with ill-defined problems and do not contain instructional support in their pure form. However, it is possible to have instructional support features in simulation environments. Instructional support features like scaffolding, advising, feedback, and model transparency can be built into the simulation environments to accommodate the needs of FD students. Previous research on instructional support features in simulation environments shows the importance of these strategies. However, there is limited research on their interaction with cognitive styles; yet Reiff (1996) claimed "FI may also be a significant factor in the learning of concepts from higher order uses of computers (simulation games and applications)" (p. 233). Also, Angeli & Valanides (2004, p. 34) stated "… cognitive style and other cognitive factors …

may interfere with the desirable effects expected from learning with dynamic modeling tools."

Williams (2001) investigated the interaction between the FD/FI cognitive style and conceptual models in simulation environments, and their effects on students' performance. She implemented conceptual models in advance organizer forms in a simulation environment to support FD students during problem solving activities. This instructional support feature failed to provide enough structure for FD students in the simulation environment. As discussed before, not all strategies are suitable for all learning environments. Even though implementing advance organizers provided enough structure for FD students in other environments (Meng & Patty, 1991), this study showed that this instructional support feature was not helpful enough in simulation-based learning environments.

In another study, Angeli and Valanides (2004) investigated different versions of instructional support in simulation environments and their interaction with the FD/FI cognitive style. The instructional support provided in this study was the model transparency that provided the explanation of the underlying model used for the simulation. Since both groups received some type of instructional support, the researchers focused on the interaction between the format of model transparency provided and the FD/FI cognitive style. When the participants were provided with text-only instructional support, the results of the study showed no significant difference in terms of performance in this simulation environment. Since both groups had some forms of instructional support, it is not possible to conclude that model transparency in text-only format does provide enough structure for FD students to succeed in simulation based learning environment. Therefore, there is a need for a further study to clarify this issue.

This is especially important since simulations' individualistic, active, hypothesis-testing features favor FI students, not FD students who rely on others' approval to learning (Ford, 2000; Witkin et al., 1977) and have a tendency towards a "spectator" approach to learning (Ford, 2000).

Assumptions

- Not all students perform equally when they are provided with a single form of instruction.
- Instructional materials and learning environments can be adapted to accommodate different cognitive styles. Even though the majority of research supports this assumption, it is important to mention some conflicting results.
- The simplified underlying model for this simulation was accurate enough to simulate a real life pond ecosystem. Simplification increases the simulation's educational value, because of the complex nature of the ecosystem simulated.
- The scoring system integrated into the simulation was adequate for measuring students' practical performance on the topic.

Limitations

- The sampling size for this study was small; therefore, special caution should be paid in interpreting or generalizing the results.

- Voluntary participation in the study limits the generalizability of the findings to all students.
- The impact of other individual differences such as attitudes toward learning, attitudes toward using simulations and simulation-games, computer literacy level, other dimensions of learning and cognitive styles, motivation, educational level, and other factors that may have influenced learning was not measured.

Delimitations

- The simulation did not exactly replicate real life situations. This is one of the characteristics of educational simulations. Real life situations consist of numerous intervening variables, and there are two reasons for not including all the variables in the simulation. One is that it is impossible to define all of the variables and their effects in the studied system. Another is that even if it is possible to define some of these variables, their effects on the system are insignificant for the purpose of education. For example, in a physics simulation that simulates the free-fall phenomenon, the effect of air current is very limited and therefore should be avoided especially if this simulation is designed for novice students with no or little previous knowledge of the topic. Though simulations are designed to simulate real life systems, their main goal is to create an appropriate learning environment for students.

- The time allotted for the students to interact with the simulation was 20 minutes for practice session. The time limit was used to restrict the time spent on interacting in the simulation environments.

Definition of Terms

Black-box Model: A model in which none of its components are visible. Users are only allowed to see the inputs and outputs.

Feedback: Feedback refers to the responses displayed to simulation users immediately after their decision in the simulated environment. The nature of these feedback messages is diagnostic. With feedback messages, the users were provided with cues about what went wrong in previous years. Additionally, feedback provides guidance for future years.

Glass-box Model: A model in which all or some of its components are visible. In this model, users are informed about relationships between each component.

Simulation: The term simulation was used based on Alessi (2000a) definition. Simulation is “a program that incorporates a model that the student can manipulate and for which the learning objective includes understanding the model” (p. 176). The simulation used for this study was a Web-based conceptual simulation.

Simulation Performance: Simulation performance was measured by total fish harvested during 15 simulated years. In this study, simulation performance shows participants practical performance (as opposed to conceptual performance).

Organization of the Study

This study is organized into five chapters. Chapter I provides an introduction to the study. It includes a brief background information about the FD/FI cognitive style, problem statements, purpose, assumptions, limitations, delimitations, importance of the study, and definitions of terms.

Chapter II presents a review of the literature. There are two main parts of this literature review. In the first part, the characteristics of FD and FI individuals, main assessment tools to measure individuals' FD/FI cognitive style tendency, and possible educational applications of the FD/FI cognitive style are explained. In the following part, how students' cognitive style preferences affect their achievement and the relationship between the FD/FI cognitive style and intelligence are discussed. This part ends with the discussion of research on the strategies used for accommodating the needs of FD students in various educational settings including computer-based instructional materials and learning environments. In the second part, background information on computer-based simulations and simulation-games, classifications of simulations, and educational uses of simulations are discussed. This part is finalized by discussing the role of the FD/FI simulations and the strategies implemented to accommodate the needs of FD students in these learning environments.

Chapter III describes the research methodology including the process of designing and developing the simulation-game, the selection of participants, assessment tools to be used, research design, and data analysis methods.

Chapter IV discusses the results of the study, and finally Chapter V provides the conclusions and recommendations for further research.

Time Schedule

The following time schedule was followed during this research study.

Study design (Spring 2005 – Fall 2005)

Data collection (February 2006)

Data analysis (February/March 2006)

Summary

In the first chapter of this study, the necessity of accommodating the needs of FD students in various learning environments is discussed. While the research investigates and suggests some instructional strategies to decrease achievement discrepancies between FD and FI students in computer-based instructional materials and learning environments, there is limited research regarding simulations and simulation-games. Since not all instructional strategies accommodate the needs of FD students in every educational environment, the need for further studies investigating possible ways of accommodating the needs of FD students in simulation environments is supported in this chapter. In addition, this chapter also includes limitations, delimitations, assumptions, organization of study, and time schedule for this research study.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

This chapter has three objectives. The first objective is to present the relevant review of the literature on the FD/FI cognitive style and its educational applications. The second objective is to present the review of the literature on educational simulations, and their educational implications. The last objective of this chapter is to present and discuss the role of the FD/FI cognitive style in simulation design.

Characteristics of FD/FI Students

Cognitive style research comprises a major part of the individual differences literature. Cognitive style is defined as “an individual's preferred and habitual approach to organizing and representing information” by Riding & Rayner (1998, p. 8). Riding and Cheema (1991) identify more than 30 different cognitive style dimensions in the literature. One of these cognitive styles, the FD/FI cognitive style, was determined and developed by Herman A. Witkin and his collogues during late ‘40s. Among the cognitive styles, the FD/FI cognitive style is one of the earliest and the most researched cognitive style in the literature (Witkin et al., 1977).

FD and FI are not two distinct states of perception categories. Everyone’s perception is spread between these two extremes (Witkin et al., 1977). While individuals closer to FD extreme have similar cognitive processing and perception tendencies, individuals closer to FI extreme have differing cognitive processing and perception tendencies. These tendencies affect many aspects of their life including how they learn. Individuals with FI tendencies have analytical, competitive, and individualistic perspectives, and a preference for self-defined goals, strategies, and reinforcement. FI individuals are less affected by predetermined structures and authority figures. Since they are not affected by their surroundings, they are able to select appropriate information from any kind of instructional material. FI individuals prefer to create their internal structure during learning (Meng & Patty, 1991). Individuals with FD tendency have more group-oriented, global, socially sensitive perspectives and a preference for learning in groups, externally defined goals, reinforcements, and clear definitions of desired outcomes. FD individuals need external structures and prefer authority figures. Since they depend on external structures, they are not able to extract appropriate information from instructional materials unless cues are saliently provided (Witkin et al., 1977).

Measurement Tools

Witkin et al. (1977) reviewed the studies on the FD/FI cognitive style. In their review of the studies, Witkin et al. listed the following measurement tools, which are designed to determine individuals' FD/FI cognitive style tendency.

Frame and Rod Test: This test was developed by Witkin and Ash. Testing happens in a dark room; a luminous rod and a frame are provided in this room. Both rod and frame are adjustable. The frame is tilted to a fixed position in a test taker's absence.

The test taker is asked to adjust the tilted rod to upright position. The amount of tilting in degrees is used for determining the test taker's cognitive style. When a test taker uses the tilted frame as his/her guidance, then his/her cognitive style is determined as FD (if the frame is tilted 25º to left, then FD individuals arrange the rod closer to 25 º to the left). When a test taker uses his/her felt position of body as a reference (real upright position) during adjustment, then his/her cognitive style is determined as FI.

Body Adjustment Test: This test was also developed by Witkin. The testing tools consist of two main items: an adjustable seat and an adjustable small room. Both the seat and the room are tilted in a test taker's absence. The test taker takes the seat facing towards the small room (only able to see this room). During the testing process, the test taker is asked to adjust his/her body to upright position. The amount of tilting in degrees is used for determining their cognitive style. Individuals who use the tilted room for reference are determined as FD, and individuals who use their felt positions of body (real upright position) are determined as FI.

Embedded Figures Test (EFT): This paper-based test was developed by Philip K. Oltman, Evelyn Raskin, and Herman A. Witkin. During testing, test takers are asked to "locate a previously seen simple figure within a larger complex figure which has been so organized as to obscure or embed the sought-after simple figure" (Witkin, Oltman, Raskin, & Karp, 2002, p. 1). This perceptual test is conducted at the individual level. Modified versions of the EFT are available for groups (Group Embedded Figures Test or GEFT) and for children (Children's Embedded Figures Test or CEFT). The EFT and its modifications (especially the GEFT) are criticized for only measuring for FI (Hall, 2000;

Riding & Mathias, 1991); lack of contrasting measurement towards FD causes the results of EFT and GEFT to be blended with ability (Hall, 2000). However, Hall (2000) claimed that "the EFT or GEFT will likely remain the most common measure of field articulation" (p. 10) due to its easy administration.

In addition to the tests created by Witkin and his collogues, there are other testing instruments available to determine individuals' FD/FI cognitive style tendency.

Cognitive Style Analysis: This computer-based measurement tool was created by Riding in 1991. Even though its main goal is to determine two types of cognitive style dimension (wholist/analytic and verbal-imagery), the wholist/analytic cognitive style is seen as similar to the FD/FI cognitive style dimension (Chen, 2002; Ford, Miller, & Moss, 2001; Riding & Cheema, 1991; Riding & Rayner, 1998). In this tool, the measurement is not only for FI, but also for FD (Riding & Cheema, 1991).

In addition to these tools, Jonassen and Grabowski (1993) listed four other measurement tools for measuring individuals' FD/FI cognitive style tendency mentioned in the literature. These are:

- Hidden Figures Test
- Closure Flexibility Test
- Auditory Embedded Figures Test
- Tactile Embedded Figures Test

FD/FI and Intelligence

The difference between cognitive style and intelligence is explained by Riding and Rayner (1998) as:

> Both style and ability will affect performance on a given task. The basic distinction between them is that performance on all tasks will improve as ability increases, whereas the effect of style on performance for an individual will be either positive or negative, depending on the nature of the task. It follows from this that, for an individual at one end of a style dimension, a task of a type they find difficult will be found easier by someone at the other end of the dimension, and vice versa (p. 11).

Even though FD/FI was defined as a cognitive style by Witkin et al. (1977) and generally accepted by many researchers, some researchers challenged this claim (see Moran (1985), Jonassen & Grabowski (1993), and Zhang (2004)). Jonassen and Grabowski (1993, p. 4) listed the five main types of individual differences as: intelligence, cognitive controls and cognitive styles, learning styles, personalities, and prior knowledge. Cognitive controls were defined as "the psychoanalytic entities that regulate perception" (p. 83) and due to their unipolar nature, they are located closer to intelligence than cognitive styles are. Jonassen and Grabowski claimed that there is no neutral value for cognitive controls. However, they informed that cognitive controls maintain significant aspects of cognitive styles. According to these authors, FD/FI is a cognitive control.

Witkin, Faterson, Goodenough, & Birnbaum (1966) examined the cognitive patterns in mildly retarded boys, and compared to the results with the studies on normal boys. For this study, the body adjustment test, the rod and frame test, the EFT, and the Children Embedded Figures Test were used to identify cognitive style. Participants also took a verbal comprehension intelligence quotient (IQ) test (Wechsler Adult Intelligence Scale (WAIS)) and an analytical IQ test (Wechsler Intelligence Scale for Children (WISC)). The authors articulated one of the results of the study as follows: “Among the retarded, as in normals, measures of field dependence (i.e., analytical competence) and figure-drawing sophistication-of-body-concept scores related significantly to prorated analytical IQ’s but not to prorated verbal comprehension IQ’s.”

Cooperman (1980) investigated whether field dependence was a measure of general intelligence. Subjects of this study (412 undergraduate college students) participated in a rote-learning task (equivalent to memory drum procedure) and a verbal reasoning task. To identify the participants’ cognitive style, the GEFT was implemented. The result showed statistically significant differences between FD and FI individuals. FI individuals scored higher than FD students did in both rote learning task and verbal reasoning task. Cooperman disagreed with Witkin et al.’s (1966) findings and stated that FI individuals were superior to FD individuals in all cognitive areas, not only tasks subsumed under the analytical index.

Tomala and Pawelkiewicz (1978) investigated the relationship between the FD/FI cognitive style, intelligence, and social class. One-hundred and fifty children’s cognitive styles (using kindergarteners, second and third grade students) were tested with the Rod and Frame Test. Since the main goal of the study was to investigate the relationship between social class and the FD/FI cognitive style, the effect of intelligence was used for control purpose. Otis-Lennon intelligence tests (forms J and K) were implemented to determine intelligence scores for the participants. The study results showed that there was a moderate positive linear relationship (statistically significant) between intelligence and the degree of field independency. Additionally, when controlled for intelligence, the relationship between social class and the FD/FI cognitive style was insignificant. Tomala and Pawelkiewicz discussed that since measures of intelligence have no direct applications for educational settings and the FD/FI cognitive style has practical applications to educational problems, the FD/FI cognitive style should be used in conjunction with other evaluative measures to facilitate learning.

While reviewing cognitive styles, Riding and Rayner (1998, p. 23) stated that the major criticism for the FD/FI cognitive style dimension is its relationship to fluid ability. However, they claim that the problem is not with the foundation of the FD/FI cognitive style, but with its measurement. According to Riding and Rayner, the EFT and GEFT do not only measure individuals' FI/FD cognitive style preferences, but also measure some aspect of intelligence because testing for the FD/FI cognitive style preference is done through testing for FI tendency as opposed to both FD and FI tendencies. This criticism about EFT and GEFT was also supported by Richardson & Turner (2000). Even though criticism focuses on the EFT and the GEFT, similar conclusions are reached by using other measurement tools. While Tomala and Pawelkiewicz (1978) and Witkin, Faterson, Goodenough, & Birnbaum (1966) implemented other measurement tools such as the Rod an Frame Test, they found correlation between the FD/FI cognitive style and some measurements of intelligence.

Even though the relationship between intelligence and the FD/FI cognitive style is mentioned in some studies as one of the limitations, research on the FD/FI cognitive style provides useful information for solving some of the educational problems in educational settings. Therefore, many researchers focus on the effects of the FD/FI cognitive style in various educational settings.

The FD/FI Cognitive Style and Academic Achievement

According to Jonassen and Grabowski (1993), individuals' cognitive styles affect their selection of study area and the courses they take. Additionally, it is claimed that various cognitive styles influence individuals' performance in the classes they take (Drysdale, Ross, & Schulz, 2001). The FD/FI cognitive style is also found to be related to academic performance of individuals; FI students are seen as favorable in educational settings (Reiff, 1996). Hall (2000) stated that "Field dependent students typically perform less well than field independent individuals in most instructional environments" (p. 67). This statement was supported by many research studies (Dwyer & Moore, 2001; Hall, 2000; Kush, 1996; Luk, 1998a; Reiff, 1996). These studies represent various fields of study, different ethnics, and age ranges. Some of these studies are discussed below.

One of these studies was done regarding reading achievement by Fehrenbach (1994). Thirty gifted and 30 average readers from eighth, tenth, and twelfth grade students were given the Hidden Figures Test (HFT) to classify their cognitive styles as either FD or FI. The Iowa Test of Basic Skills-Comprehension Subtest (over 95th percentile) and Wechsler Intelligence Scale for Children-Revised (score of 130 or more) test results were used to determine giftedness. Gifted readers were found to be more FI than the average readers were. While the average HFT score was 14.833 for gifted readers, the average HFT score was 8.500 for average readers from a possible score range of 0 (extremely FD) to 26 (extremely FI). During the study, all the readers implemented similar reading strategies; however, the frequency of reading strategy implementation was varied based on both their reading comprehension level (gifted or average) and their cognitive style. The study showed that FI readers summarized more accurately than FD readers did. Another study on reading achievement was done by Rosa (1994). Rosa investigated the effects of the FD/FI cognitive style on the reading success of fourth-grade African American male readers. The GEFT was used to assess the cognitive styles of forty-three students. The study produced similar results to Fehrenbach's study; FI readers outperformed FD readers on reading comprehension tests.

In addition to reading, some researchers focused on the effects of the FD/FI cognitive style on math achievement. Kush (1996) examined the relationship between the FD/FI cognitive style and reading and math achievement test scores in Anglo and Mexican 4th grader students. The results of the study showed that the FD/FI cognitive style is one of the predictors of academic achievement in both reading and math, where FI is favorable. Clark, Seat, & Weber (2000) found that there was a positive relationship between higher GEFT results (FI tendency) and success performance index (high school GPA times 10 plus mACT) in undergraduate engineering students, where mACT refers to mathematics ability part of American College Test (ACT). A similar study by Cano

(1999) showed that the ACT and grade point average (GPA) scores were correlated with GEFT scores for undergraduate agriculture students.

Recent studies focus on the effects of the FD/FI cognitive style in computer-based instructional materials. Weymer (2002) examined the influence of the FD/FI cognitive style on the success of 6th grade students in modular technology education. In addition to the FD/FI cognitive style, the effects of verbal ability, quantitative ability, prior knowledge, and motivation were investigated. The GEFT was used to assess the students' cognitive styles; based on GEFT scores, students were categorized as FD, field intermediate, and FI. For this study, "subjects scoring within one half standard deviation of the mean are considered to be field intermediate" (p. 38). In some research studies, this group is called "field neutral." A computer-assisted instructional (CAI) multimedia presentation was used for this study. Even though the FD/FI cognitive style was not found to be a significant factor in explaining achievement, the results showed that FI students outperformed both field intermediate and FD students. In a similar area, a meta-analysis of nine research studies dealing with the FD/FI cognitive style and its effects on hypermedia environments by Chen (2002) reported that FI students perform better in multimedia learning environments.

Another area of interest is the effects of the FD/FI cognitive style on academic achievement in online learning environments. Luk (1998b) discussed the results of two studies dealing with the effects of the FD/FI cognitive style in an online learning environment. In both studies, significant positive correlations between the GEFT scores and course grades were found. In a recent study, DeTure (2004) investigated whether self-efficacy and the FD/FI cognitive style could be used to predict the achievement of students (in terms of GPA) in online courses. Seventy-three students who enrolled in one of six online general education courses participated in this study. They found that FI students had higher online technology self-efficacy; however, neither self-efficacy nor the FD/FI cognitive style was a good predictor of achievement. Shih & Gamon (2001) reported similar results.

In her study dealing with effects of the FD/FI cognitive style on achievement in computer programming classes, Bishop-Clark (1992) performed a meta-analysis of 10 studies with 12 effect sizes. The average effect size was .45. FI students consistently earned higher grades regardless of programming language, age, or assessment tools used for measuring the FD/FI cognitive style. In a recent study, Baker and Dwyer (2005) reported a meta-analysis of eleven studies (a total of 1341 participants) conducted with same instructional materials and the same measurement tools (a comprehension test, a drawing test, an identification test, and a terminology test). In all of these studies, the GEFT was used to assess the participants' cognitive style as either FD or FI. The results supported the previous research about superior performance of FI students.

While a majority of the studies reported superior performance of the FD students, there were some studies with no significant differences. Due to lack of detailed information about the design and development of instructional materials used in these studies, it is not possible to discuss the reasons for these contradicting results. It is speculated that the instructional strategies implemented in these studies might have been designed to accommodate the needs of FD individuals, allowing them to decrease the achievement discrepancy.

FD/FI Cognitive Style and Its Educational Applications

As discussed, the characteristics of FD and FI students are very different, and these characteristics interact with instructional materials and learning environments in different ways. Since these characteristics are consistent among individuals who share the same cognitive style preferences, their preferences in educational settings are also similar. Many research studies investigate these interactions. This type of research is called aptitude-by-treatment interaction (ATI). Jonassen and Grabowski (1993), by state that "Even a simple awareness of learner traits and the possible interactions with learning and instruction will improve our understanding of those processes and the quality of our educational efforts" (p. 31). ATI research results reveal information about how instructional designers and developers can improve learning activities and instructional materials based on their interaction with the FD/FI cognitive style. Even though the effectiveness of cognitive style treatments was challenged by some authors, such as Merrill (2002), many researchers found it useful and conducted ATI research. Some of these research studies are discussed next.

Some researchers focused on the learner traits that can be used to improve instructional materials. Dwyer and Moore (2001) investigated effects of color coding (black & white and color) on the achievement performance of students with different cognitive style (FD/FI) and gender. The GEFT was implemented to categorize the participants' cognitive style as FD, field neutral, and FI. Two versions of the same instructional booklet were used, one with black and white images and another with color-coded images. One hundred eighty students completed four different tests (drawing, identification, terminology, and comprehension), and then the scores of these tests were combined to create one criterion score. The results of the study showed that FI students outperformed FD students when black & white treatment was implemented. However, there was no significant difference in the achievement performance of FD and FI students when color treatment was implemented. In addition, an interaction between gender and treatment was found; females who received color treatment achieved significantly higher scores than females who received black & white treatment. The authors concluded that "the color-coded illustrations provided a sufficient structure for the FD learners to interact with and internalize at levels similar to that achieved by the Fl learners" (p. 315)

In a similar study, Worley and Moore (2001) investigated an interaction between the FD/FI cognitive style and use of colors in visual imagery of the instructional materials. Four versions of instructions with different color treatments were created: black and white, realistic colors, black and white with portions highlighted in single color hue, and black and white with portions highlighted with real color. Identification and terminology tests were used in this study. While FD students who studied with instructional materials with black and white images and in real colors achieved lower scores in both tests than other two types of instructional materials, these differences were not statistically significant. In all cases, FI students outperformed FD students.

Hite (2004) investigated effects of reading content on reading comprehension among FD and FI readers. The researcher investigated whether reading social content would make any difference in comprehension. Two passages, one with social content and one with non-social content, were used in the study. The participants were ninety undergraduate students; and the GEFT was implemented to determine participants' cognitive styles as either FD or FI. FI students outperformed FD students in reading comprehension test when students dealt with a passage with non-social content; however, no statistically significant difference was found when the students dealt with a passage focused on social content.

While some researchers focused on instructional materials, such as color-coding, other researchers investigated the issues regarding learning process in a classroom environment, like cooperative team composition and note taking. Miller and Polito (1999) investigated effects of cooperative learning compositions on performances of students with different cognitive styles. The GEFT was used to assess ninety undergraduate students' cognitive styles (FD, field neutral, and FI). Based on their cognitive style, students were assigned to one of the four teams. The compositions of these teams included FD students only, FI students only, field-neutral students only, and mixed. Even though FD teams attained the lowest teamwork grades and class grades, this difference was not statistically significant. Based on study observations, the authors pointed out that homogeneity of the teams was important for the cooperative work. Mixed teams had difficulty working together effectively. However, there were no statistically significant differences in students' achievement scores between teams with different compositions. Even though the authors claimed no effect, when we consider that FI students are more successful in academics based on literature, the results of the study can be interpreted to show that the social side of cooperative learning helps FD students to perform equal to FI students.

In another study, effects of note taking and signaling text during listening on the recall of the text for FD and FI individuals were studied by Rickards, Fajen, Sullivan, & Gillespie (1997). The authors reported two different studies; forty participants were given the EFT to determine their cognitive styles as either FD or FI in one of these studies. The study results showed that note taking and signaling were not effective when implemented alone, but there was an interaction between these two variables for FD students. FD students achieved higher recall scores when they took notes in the presence of signals, but FI students who received this treatment when they took notes did not achieve higher recall scores. The authors concluded "…FDs recalled as well as FIs only when allowed to take notes while listening to signaled text" (p. 512).

In addition, some of the researchers investigated the interaction between students' cognitive style and teacher's cognitive style. Saracho (2003) discussed the results of previous research on this issue. She concluded two types of matching, "identical cognitive style matching," and "performance cognitive style matching." While identical cognitive style matching suggests considering the students' cognitive style and their needs in classroom environments, performance cognitive style matching suggests extending students' cognitive style by challenging their preferences. She explained that performance cognitive style matching helped students to overcome the limitations of their cognitive style preference. She noted that research on former type of matching created dubious results, while research on latter type of matching was insufficient. She stated that it was almost impossible to generalize the results of research on the identical cognitive style matching, but it was promising. She concluded that teachers should know about the FD/FI cognitive style, and provide a variety of instructional strategies to adapt instructions to students' needs.

Witkin et al. (1977) stated that the FD/FI cognitive style has the widest applications to educational problems and argued that modifying learning approaches for cognitive styles may help to enhance the learning process. Some of these modifications for FD and FI students were discussed by Witkin et al. For FD students, learning appears to be facilitated by presenting overviews of materials, providing structured group-learning environments, and nurturing teachers. FI students prefer details, less structure, independent discovery learning situations, and formal attitudes from their instructors.

Research on the FD/FI cognitive style has allowed both teachers and instructional designers to see the effects of different learner traits. At the same time, it has helped teachers and instructional designers to understand the needs of FD students, and has provided with possible ways to accommodate their needs in various instructional materials and learning environments, so the discrepancy in achievement between FD and FI students can be decreased. In face-to-face learning environments, the existence of a teacher provides FD students with authority figure, and lectures are generally structured. However, with the vast use of computers and the Web in educational settings, learning becomes more and more learner driven. Absence of an authority figure and multimedia aspects of computer-based learning environments increase the importance of accommodating the needs of FD students in these learning environments. In the following section, effects of the FD/FI cognitive style in computer-based instructional materials and learning environments and different instructional strategies to accommodate the needs of individuals within these environments for different cognitive styles is discussed.

Needs of FD/FI Students in Computer-based Instructions

According to Chen and Paul (2003), non-linear interactions were the most important advantage of computer-based instructional materials. They discussed that through non-linear interactions, users were able to select their own learning paths, and decide on the pace of information. Yet, Chen and Paul questioned the effectiveness of non-linear interactions because not all students appreciated being given control in learning environments. In addition to non-linearity feature, other design issues that are present in other learning environments exist in computer-based instructional materials as well. Some of these design issues are related to content (such as dept of content and structure), while others issues are related to interface design (like use of color, user control, media selection, and navigation).

Meng and Patty (1991) investigated the effectiveness of organizers in computer-based instructional materials for individuals with different cognitive styles. The four types of organizers implemented in this study were a written advance organizer, a written post organizer, an illustrative advance organizer, and an illustrative post organizer. The researchers found that illustrative advance organizers were helpful to FD students and increased their performance. Field intermediate students benefited from illustrative post organizers. However, use of organizers did not have any effect on the performance of FI students.

Khine (1996) investigated the interaction of the FD/FI cognitive style and varying levels of feedback in a multimedia presentation. The participants for the study were 105 elementary students, and the GEFT was used to determine their FD/FI cognitive style. After the multimedia presentation, the students were randomly divided into three groups. The first group received no feedback during their practice test. The second group received feedback in the knowledge of result form, which provided only whether an answer was false without any explanation. The third group received elaborative feedback, which provided the students with not only whether an answer was false but also why it was false and what was the correct response. The results of the study showed that participants in the knowledge of result feedback group and the elaborative feedback group outperformed participants in the no-feedback group. However, there was no statistically significant difference in the performance of participants they received either knowledge of result or elaborative feedback. However, the results of the study also revealed that FD participants in the knowledge of result feedback group scored higher than FD students did in the other two groups. On the contrary, FI students in the knowledge of result feedback group scored lower than FI students did in the elaborative feedback group, but scored higher than FI students did in no-feedback group.

Gheina and Chen (2003) examined students' preferences and perceptions in multimedia learning environments. They used twelve different movie clips with different characteristics: color depths (color vs. black & white) and different frame rates (5, 15, 25 frames per second). The characteristics of these clips were defined by their dynamism, use of audio, use of video, and use of text. Not all movies equally affected the performances of students with different cognitive styles. FD students preferred and understood the movies better when movies did not have distracting factors, such as text. The dynamism of the movie clips negatively affected all students' understanding of the content; however, FD students were affected the most.

Chuang (1999) investigated effects of different multimedia presentations and their interaction with the FD/FI cognitive style in instructional multimedia environments. Four different versions of presentations were implemented for an introductory physics courseware in this study; these were animation + text, animation + voice, animation + text + voice, and free choice. The results of the study showed that students in the animation + text + voice group outperformed students in both the animation + text group and the animation + voice group regardless of their cognitive style. FI students benefited from combining text, narration, and computer animation; combining different multimedia presentation-modes did not provide enough advantage for FD students. Even though it was not statistically significant, FD students scored lowest in the instructional multimedia with animation + text presentation mode.

In a similar study, Ford and Chen (2001) explored the effects of matching the presentation styles and students' cognitive style preferences in computer-based instructions. Two different navigational patterns were implemented for the same computer-based instruction about creating HTML. One navigational pattern was depth-first for accommodating the needs of FD students, and the other navigational pattern was breadth-first for FI students. However, to create the mismatching condition, half of the FD students were assigned to a group that received instructions in a breadth-first navigational pattern, and some FI students were assigned to another group that received instructions in depth-first navigational pattern. The result of this study showed that students' conceptual knowledge gain in the matching condition was significantly higher than students' gain in the mismatching condition was. However, practical performance was not affected by matching or mismatching conditions.

Hsu and Dwyer (2004) examined the effects of varied levels of adjunct questions on the performance of FD and FI students in a hypermedia learning environment. In this study, three different versions of the same hypermedia learning environment were provided; one with comprehension questions, one with factual questions, and one with no questions. A test used for achievement measured understanding of the topic. Among FI students, only the comprehension question group outperformed the no-question group. There was no other significant difference among the groups. However, FD students in the comprehension questions group outperformed FD students in the other groups. Additionally, FD students in the factual questions group outperformed FD students in the no-question group. Researchers noted that the questions provided in this instructional environment provided FD students with salient cues. Since these clues directed FD students' attention to information to be learned, their performance was improved. The authors also discussed that higher-order questions might have "a broader facilitative effect" for FD students, helping them to improve their performance further.

In another study, Alomyan and Au (2004) investigated the effects of the FD/FI cognitive style, achievement motivation, prior knowledge, and attitude on achievement in an online course. In the design of the online course, the researchers accommodated the needs of FD students with several techniques. Navigational cues were integrated into the online course for helping FD students with guiding and minimizing the navigational disorientation. Concept maps were used for providing FD students with "a global picture on the topic and to show relationships among the concepts." A graphic-based overview was also implemented for FD students. The results of the study showed no significant differences in achievement between FD and FI students. The instructional strategies implemented by the researchers helped FD students to achieve higher grades in the online course, resulting in similar success rate with FI students. The authors concluded that online learning environments can be designed to accommodate the needs of FD students, so that achievement discrepancy between FD and FI students can be minimized.

Kahtz & Kling (1999) investigated the role of the FD/FI cognitive style in the use of computer-based instructions. They reported that the experience of FD and FI students was in accordance with the cognitive style theory. While FD students did not feel that using computer-based instructions was beneficial to them, FI students felt the benefit. Both FD and FI students preferred face-to-face traditional learning to learning from the computer-based instructions. While FI students preferred laboratory environments, FD students mentioned their preference for discussions in laboratory studies. In addition, FD students stated the need for more structure in computer-based instructions.

Conclusions

Darwazeh (1994) articulated that instructional design models are very important for creating effective instructional materials and emphasized the importance of considering other individual differences, such as the FD/FI cognitive style. Since this cognitive style affects an individuals' approach to information processing, FD and FI students have quite different approaches in learning environments. FI students are generally more successful in educational environments. Even some researchers have suggested that the FD/FI cognitive style was another measurement of intelligence. Is spite of existence of these claims, many research studies showed that, the performance of FD students can be improved in classroom environments with the implementations of different instructional strategies. These strategies help to reduce the achievement discrepancy between FD and FI students.

In addition to classroom settings, cognitive styles also had significant effects on learning from learning environments that deploy hypermedia techniques (Chen & Paul, 2003). The FD/FI cognitive style was found to be important in the design of multimedia and computer-based instructions (Ford & Chen, 2001). It was claimed that empirical research on cognitive styles could provide concrete prescriptions for developing student-centered programs that match with the particular needs of each student (Chen, 2002; Ford & Chen, 2001). However, Ford and Chen discussed that matching the needs of individuals with different cognitive styles was not an easy process, as it "… may entail complex interactions with other factors such as gender, and different forms of learning" (p. 21).

Even though the issues related to matching students' cognitive style needs in computer-based instructions are well researched, multimedia and computer-based instructional environments are not the only computer-based technologies implemented in educational environments. Other technologies such as educational games and simulations are finding increasing place in educational environments. In the following section, these technologies and their interaction with the FD/FI cognitive style are discussed.

Educational Simulations and Games

The history of computer-based simulations and simulation-games is almost as old as the history of computers. The emergence of new computer technologies and advanced programming opportunities are two main factors that provide educators with more realistic and user-friendly simulations. The innovation of the Web provided one additional delivery platform for many simulations and simulation-games that simplify the access for users (Pillutla, 2003). Almost fifty years after its first implementation in a classroom (Faria & Wellington, 2004), the value of educational simulations is generally accepted in many educational fields. For example, Faria and Wellington (2004) stated that among all disciplines at American Association of Collegiate Schools of Business member schools, 97.5% of schools have a simulation implemented in at least one class. According to their survey results, 30.7% of the faculty members in these schools had been using simulations, and 17.1% were former users.

Alessi defined computer simulation (2000a) as "a program that incorporates a model that the learner can manipulate and for which the learning objective includes understanding the model" (p. 175). Simulations and simulation-games provide students with practice opportunity within simulated environments. Simulations were seen part of the computer-based instructions (Romiszowski, 1986, p. 307); and simulation was also a genre of games (Prensky, 2001). However, Prensky discussed that simulations and games were different. While simulations simulate something from real life, games do not necessarily simulate real life. While reaching the pre-determined goal is important for games, there might not be a goal for simulations. However, there is an overlapping area between games and simulations, which is called "simulation-games." While simulation-games simulate something from real life, they also have some rules, and possibly a goal to reach. According to Prensky (2001), a simulation existed when a simulation had "fun, play, rules, a goal, winning, competition, etc" (p. 212).

Understanding what constitutes a simulation is important for sound research. Gredler (1996) explained this issue by stating "the variety of disciplines attempting to develop games and simulations, the result is a variety of truncated exercises often mislabeled as simulation" (p. 521), and stated that it was one of the main problems simulation and gaming research faces. Additionally, Alessi (2000a) stated that many researchers have used the term of simulation for some specific type of simulation, and the results of these studies were applicable to only these kinds of simulations. Therefore, knowing the classifications of simulations and simulation-games is important to understanding the simulation and gaming research studies.

According to Pillutla (2003), simulations can be classified based on their implementation methods; stand-alone and distributed simulations. Stand-alone simulations cannot be distributed over the network; this type of simulations can only be reached and interacted from one machine. On the other hand, the distributed simulations can be reached from a network. Three subcategories of distributed simulations are client-server based, internet-based, and Web-based simulations. Client-server based and internet-based simulations may require specific software to be installed on computers and the access to these simulations is not easy; however, these types of simulations provide a more secure and protected environment. Even though Web-based simulations have high initial cost and management requirements, this type of simulation is the easiest one to manage once it is settled. Since the Web is independent of platforms, Web-based simulations are almost universal, and can be reached from different platforms like Microsoft Windows, Mac, or Linux machines.

Lee (1999) classified simulations as hybrid and pure simulations. He defined a hybrid simulation as "… mixes pure simulations and some features of expository instruction" (p. 72). A hybrid simulation is enhanced by embedding other instructional resources into the learning environment, so students can interact with this information, and then put their knowledge into the practice in the simulated environment. On the contrary, neither guidance nor information is provided for students in the simulation environment when this simulation is in the pure form.

Additionally, Alessi (2000b) discussed two different classification methods for simulations: procedural and conceptual. While procedural simulations were used for teaching about a procedure, conceptual simulations were used for teaching about a concept. Many simulations have a combination of both procedural and conceptual features. According to Alessi, the second classification for simulations was based on “the instructional philosophy being employed.” These two approaches, discovery and expository, were located on the extremes of simulation use continuum. He described a “… continuum with discovery learning at one end and expository learning at the other. Or course, most instruction lies somewhere in between…” (p. 180).

Some classifications of simulations and simulation-games are discussed above; however, there are other types of classifications, especially for simulation-games. For example, Dondi and Moretti (2003, p. 42) listed their categorization for simulation-games as follows:

- Intrinsic vs. extrinsic games
- Hard wired games vs. “engine” and “templates” or “shells”
- Tightly linked games vs. loosely linked games
- Reflective games vs. action games
- Synchronous (real time) vs. asynchronous (turn-based) games
- Single-player vs. two players, vs. multiplayer vs. Massively multiplayer games
- Session-based games vs. “persistent –state” games
- Video- base games vs. animation-based games.
- Narrative-based games vs. reflex-based games

Underlying Models

Simulations are built on a model to represent or simulate some or all features of a real life process or phenomenon (Milrad, 2002). Only a limited number of processes and phenomenon from the real life can be exactly simulated, because of too many variables that cannot be counted and modeled. de Geus (1994) stated that if the goal of a model was to produce reliable predictions of the modeled system, then this model should be "a precise representation of reality." Rieber (1996) mentioned other scientific uses of the simulations, and stated "simulations help scientists to establish and refine existing theory and understanding of the system." When the goal is the prediction of the future, simulations have little use because it is impossible to replicate the real life exactly. However, de Geus (1994) stated that models could play an important role as an educational or training tool, because in educational environments the goal was to learn, not to predict future. A modeled environment creates a safe place, which students can interact and learn without having to fear about the consequences. According to Rieber, full representation of real life was neither necessary nor beneficial for educational simulations.

Use of Simulations and Gaming in Education

Rieber (1996) stated that the goal of educational simulations was "to teach someone about the system by observing the result of actions or decisions through feedback generated by the simulation in real-time, accelerated time, or slowed time." Simulations do not provide students with expository learning activities but experiential learning activities (Gredler, 1996). Simulations provide and require users to involve their learning in an active way (Lee, 1999). However, not all the learning happens while interacting with simulations. Debriefing is thought to be an important part of educational simulations. “Debriefing provides a link between simulation and the real world; it draws a relationship between the game events and real-world events and connects game experience and learning” (Pivec & Dziabenko, 2004).

In spite of their vast use in educational settings, a limited attention has been given to educational simulations in the field of instructional technology (Rieber, 1996). Rieber claimed that the main reason of this minimal interest was that this kind of computer-based learning environment was considered to be related to “play;” and “the word ‘play’ can invoke so many misconceptions.” The general idea of “play” was thought to be unprofessional; however, Rieber discussed that “A careful blending of their attributes offers promise in guiding the design of interactive learning environments where structure and motivation are optimized without subverting personal discovery, exploration, and ownership of knowledge.”

In their literature review, Ravid and Rafaeli (2000) determined some of the advantages of simulations and simulation-games as follows:

- Time: Ravid and Rafaeli emphasized the time compression; however, extension of time is also an advantage of simulations and simulation-games.
- Feedback: During simulations and simulation-games, automated feedback can be provided at any time.

- Inexpensive: While it is discussed that the design and development of simulations and simulation-games are expensive, controlled time and risks make these environments inexpensive.
- Familiarity: Since the use of the simulations and simulation-games rapidly grows, the familiarity of people with these learning environments increases as well.
- Motivation: Simulations and simulation-games simulate real life phenomena and processes; this realism provides motivation for the users.
- Focus: Since underlying models of many simulations and simulation-games represent only some of the real life systems; this feature "enables focus on the main issues" (Ravid & Rafaeli, 2000).

Dondi and Moretti (2003) claimed that simulations and simulation-games could bring additional advantages to education which other educational tools lacked. Dondi and Moretti listed these advantages as follows:

- High engagement of user
- Learning by doing
- Learning by active exploration
- Dynamics

Many researchers compared the effectives of instructional simulations with the traditional instruction or computer-based instruction (Lee, 1999). For example, Bernstein and Meizlish (2003) investigated the immediate and long-term effects of implementing a simulation in an American government course. In this quasi-experimental longitudinal research, the researchers investigated the effects of using simulation on students' perception of understanding concept, political cynicism, and political participation. While the simulation group was given an educational simulation to interact with, the control group did not receive any simulation. There was a statistically significant difference between the two groups in both their perceptions of understanding the concept and in their political cynicism. The students who participated in the course with simulation reported better understanding, and emerged less politically cynical. However, the effects of simulations were not immediately apparent; they appeared after some time (their responses were taken after three years). Immediately after the class, students' perception of how well they understood the concept did not differ. However, the students seemed to remember subjects taught in the simulation module better than those who did not.

In his meta-analysis, Lee (1999) reviewed 19 different studies for understanding the effectiveness of simulations. In this study, he examined effects for different simulation designs (pure versus hybrid) and their use in two different instructional modes (presentation versus practice). From 51 effect sizes, 46 effect sizes were calculated for academic achievement, and five effect sizes were calculated for attitudes toward simulations. For academic achievement, he found that the mean effect size was .41. He explained that two thirds of the students who participated in simulation classes outperformed students in the control group (classes with no simulation). He also found that the effectiveness of simulations interacted with their design types and their use mode. Hybrid simulations (instructional materials embedded in the simulations) were found to be more effective regardless of instructional modes. However, that was not the case with pure simulations (no instructional support embedded). Using pure simulations in presentation mode resulted in a negative attitude toward simulations and lower achievement. He stated “in the pure form, students may feel lost and don't know what the simulation expects them to do.” Lee concluded that the study as:

> 1. Within the presentation mode, the hybrid simulation is much more effective than the pure simulation. 2. Simulations are almost equally effective for both presentation and the practice modes if the hybrid simulation is used. 3. Specific guidance in simulation seems to help students to perform better. 4. When students learn in the presentation mode with the pure simulation, they showed a negative attitude toward simulation. (Lee, 1999, p. 71)

In addition to its pedagogical value, the value of simulation as an assessment tool is accepted in many fields (Pillutla, 2003), such as business, physics, etc. However, Thavikulwat (2004) stated that in order a simulation as an assessment tool, the simulation needs to be serious, and adds that “simulations cannot be taken seriously if they are put together haphazardly based on an architecture that is not challenged, a state of affairs that has existed for some time” (p. 245).

Building versus Using Continuum

One of the interests in the educational use of simulations has been whether and when one learns by building simulations or by using existing simulations (Alessi, 2000b; Spector, 2000). Alessi (2000b) discussed this issue and explained the simulation use continuum. At one end of this continuum, students build simulations. While at the other end, students use simulations created by other people. Bransford et al. (1999, p. 204) suggested that students might develop a deeper understanding of phenomena in the physical and social worlds if they could build and manipulate models of these phenomena. Building simulations is especially supported in system dynamics. While importance of modeling in complex domains was stated by Milrad (2002), Alessi (2000b) discussed that “there are many cases where learning may be better facilitated through incorporation of system dynamics models into more guided simulations” (p. 178).

The other extreme in this simulation-use continuum is use of existing simulations. Alessi (2000b) claimed that the majority of the simulations implemented in education and training were located at this end. Underlying models of these simulations were not visible and not changeable by users. The users interacted with the underlying model through an interface to “experience, explore, experiment, and practice” the underlying model (Alessi, 2000b). These simulations are called black-box simulations. According to Alessi, black-box simulations should be implemented in two conditions. One condition occurs when the goal of a simulation is to explore the underlying model (unguided discovery learning). Another condition occurs when a simulation is not used to teach about the underlying model, but just for teaching a proper way or steps to complete a process (like a flight simulator). In addition, if the goal of simulation is to practice a particular problem-solving strategy, again black-box simulations might be appropriate to use.

Between these two extreme points in the simulation-use continuum, there are many combinations of simulations. These are generally called glass-box simulations. In glass-box simulation environments, the underlying model is visible to some degree, while that is not the case in the black-box model. Größler, Maier, & Milling (2000) stated that “black-box simulators do not provide direct insight into the problem structure” (p. 257).

Students who are using black-box simulations have limited or no information about the underlying model and feedback mechanism. Therefore, "black-box simulators are assumed to be of limited effectiveness and efficiency in supporting the learning and problem-solving capabilities" (Größler et al., 2000, p. 257). Alessi (2000b) discussed that while black-box models were mainly appropriate for conceptual learning, both black-box and glass-box design should be considered for procedural learning. Glass-box simulations allow users to interact with the simulation interface, and to investigate the underlying model at the same time. To create a glass-box simulation, there are various options to implement a model transparency feature into a simulation environment. Some of these options were listed by Alessi as following: flow diagrams, causal loop diagrams, formulas (algebraic relations), and verbal or visual explanations and examples. Glass-box models can also provide visibility to complete underlying model or just part of it. Especially in complex models, partly visibility was claimed to be an efficient way of reducing the cognitive load by Alessi.

Zamora, Machuca, & Castillo (2000) and Machuca (2000) discussed the advantages of providing transparency to simulations (glass-box). In addition, a study by Größler et al. (2000) investigated the effectiveness of glass-box model simulations in business simulations. The results of the study showed that visibility of an underlying model had positive affects on the students' performance.

Role of the FI/FD Cognitive Style in Simulations

While some studies reported the effectiveness of simulation over other learning environments, Lee (1999) informed about the existence of conflicting results in simulation studies. He suggested that these conflicting results should be investigated further for better instructional prescriptions. He recommended that the effects of some instructional strategies such as instructional sequence, knowledge domain, and learner characteristics should be investigated. Additionally, Baker and Dwyer (2005) discussed the increasing importance of the cognitive styles in the design of all instructional materials including simulation environments.

Simulations are generally used for simulating complex domains. Complex domains are dynamic; and even small changes may cause a serious change in the whole system. This complexity is difficult to understand, especially for newcomers to a complex domain (Milrad, 2002). As mentioned, almost in all educational environments, achievement differences between FD and FI students are reported (Baker & Dwyer, 2005). This achievement difference based on the FD/FI cognitive style is expected to exist in simulation environments as well, because learning with simulations, where complex and ill-structured domains are simulated, places significant cognitive demands on students (Milrad, 2002). Additionally, simulations' active, hypothesis testing nature favors FI students, not FD students who rely on other's approval to learning (Witkin et al., 1977). While there are many studies showing how to accommodate the needs of FD students in other computer-based instructional materials and learning environments, there are only few studies investigating this issue in educational simulations.

Williams (2001) investigated effects of a conceptual model provision (in the form of advance organizers) and the FD/FI cognitive style on problem-solving performance in a simulation based exploratory learning environment. This study also investigates the effects of prior knowledge, prior experience with photography, computer playfulness, and interest in photography. The GEFT was implemented to classify sixty-one undergraduate students' cognitive styles as FD or FI. It was found that FI students performed significantly better than FD students did in simulation-based learning environments. Even though the treatment group receiving advance organizers scored higher than the control group not receiving advance organizers, this difference was not statistically important. In terms of the difference between the post-test and pre-test, there was no significant effect of either cognitive style or treatment; nor was the interaction of cognitive style and treatment. These results do not support the assumption of providing conceptual models in exploratory learning environments to accommodate the needs of FD students.

In a recent study, Angeli and Valanides (2004) investigated the effects of two types of instructional materials on the problem-solving performance of students with different cognitive styles (FD, field mixed, and FI) interacting with modeling software. Seventy-one freshmen participated in the study. The Hidden Figures Test (HFT) was employed to measure the students' cognitive style. Students explored a computer model created by the Model-It system dynamics tool on immigration policies. Students were divided into two groups; one group was provided with instructions in text-only format, while another group was provided with instructions in text-and-visual format. In text-only format, the model was described in narrative form. In text-and-visual format, the model was described not only with narrative but also with the diagrams of its subsystems. All cause and effect relationships were represented in these diagrams. The students were asked to interact with the model, and then they solved problems related to immigration issues. The researchers did not find any significant time differences between FD and FI students. Even though the students in text-and-visual group spent less time on problem solving than those in text-only session, the difference was not statistically significant. FI students outperformed field-mixed and FD students in the text-and-visual group, yet no such difference was found for the text-only group. In text-only mode, FD, field-mixed, and FI students performed equally; and their performance was equal to FD and field mixed students in text-and-visual group. According to the researchers, the text-and-visual format in instructional materials interacted with cognitive style preferences of FI students and facilitated their performance. FD and field mixed students did not benefit from text-and-visual format as their performance in a learning environment stayed at the same level regardless of the type of instructional materials used. The researchers reported that using instructions in visual format interacts with the FD/FI cognitive style in simulation based learning environments.

Summary

The first half of the chapter presented a review of research in the field of FD/FI cognitive style and its educational applications. Cognitive styles represent individuals' cognitive processing and perception tendencies. Individuals with FD and FI tendencies have different tendencies in educational environments. While FD individuals are group-oriented and prefer structured learning environments, FI individuals are individualistic and prefer creating their structures in learning environments. In order to determine individuals' FD or FI tendencies, there are various tools available. The Embedded Figures Test and the Group Embedded Figures Test are the most common tools in the literature. The FD/FI cognitive style was questioned about being another measurement of intelligence. Even though there is no consensus among the researchers about the relationship between the FD/FI cognitive style and intelligence, the majority of educational researchers agreed on the relationship between this cognitive style and academic achievement. Many research studies showed that FI individuals were generally more successful in various educational settings than FD individuals were. However, it was also claimed that the needs of FD individuals could be accommodated in learning environments with various instructional strategies. These instructional strategies tend to be different in different learning environments. The studies dealing with these instructional strategies in various forms of instructional materials and learning environments were presented in the first half of this chapter.

The second half of this chapter presented the background information about simulations and simulation-games. Simulations and simulation-games are developed on an underlying model, and the goal of a simulation is to understand this underlying model. Simulation-games are hybrid between simulations and games. While some aspects of simulation-games are similar to simulations such as simulating real life phenomena or processes, other aspects of simulation-games such as having a goal are similar to games. There are various classifications of simulations. One of these classifications is based on the instructional philosophy being employed, either expository or discovery. When a simulation is used for expository learning, the underlying model is visible. Even in some cases, students are expected to create a model for the simulation. This approach, system dynamics, has found limited implementations in educational settings. If a simulation is used for discovery learning, the underlying model is not transparent in this simulation environment. The majority of the simulations implemented in educational settings are in this category. Simulations already created and packaged, and students are expected to interact with them. These simulations are called black-box simulations. However, even if a simulation is used for discovery learning, the underlying model can still be transparent to a degree. Glass-box simulations provide the users with some degree of transparency to the underlying model. The transparency of the underlying model can be provided by various methods, including flow diagrams, causal loop diagrams, formulas (algebraic relations), and verbal or visual explanations and examples. Glass-box simulations are claimed to be more effective. Additionally, glass-box simulations are claimed to reduce the cognitive load. Nevertheless, there are limited research studies on this issue. In addition, there are a few research studies on the effects of the FD/FI cognitive style in simulation based learning environments.

The FD/FI cognitive style is believed to be interacting with simulation environments. While FI students generally outperform FD students in various educational settings, simulations' dynamic and hypothesis testing features might deepen this discrepancy in achievement. Therefore, the importance of accommodating the needs of the FD students in simulation-based learning environments increases. Existing research shows that advance organizers in simulation environments do not accommodate the needs of FD students. However, there is no research investigating the other instructional strategies. Since the effectiveness of instructional strategies is learning environment dependent, this study investigates the role of feedback and model transparency in the simulation based learning environments.

In the next chapter, the research methodology for this study is described.

CHAPTER THREE

Method and Procedure

Introduction

The purpose of this study was to investigate the interaction between the FD/FI cognitive style and two different design strategies implemented during the development of simulations. Since FI students were generally found to be more successful in educational environments, this study investigated whether instructional strategies implemented in one of the design models could be used to accommodate the needs of FD students in simulation environments. The study questions are listed in this chapter. Additionally, this chapter details the research methods and procedures for this research, including the selection of subjects, explanation of the instruments, and the procedures used to collect and analyze the data.

Research Questions

This study was designed to answer following questions.

1. What are the differences in simulations performance between two groups (black-box simulation without feedback and glass-box simulation with feedback)?
2. What is the relationship between simulation performance and the subjects' degree of field independency?

a. What is the relationship between the subjects' degree of field independency and their simulation performance in a black-box simulation with no feedback?

b. What is the relationship between the subjects' degree of field independency and their simulation performance in a glass-box simulation with feedback group?

3. How does the subjects' degree of field independency interact with two versions of simulation in order to explain their simulation performance?

Subjects

The subjects of this research were undergraduate and graduate students aged 18 and older from the University of Tennessee at Knoxville. Participation in the research was voluntary and there were no special characteristics sought and no special requirements for participation. Upon approval of using human subjects in the research study, the invitation to the study was delivered by using a listserv that was targeted for the teacher education interns in a large southeastern university. Before the invitation was sent, the required permission had been granted me by the listserv moderator. However, other means of invitation to the study were also implemented; including invitation in various classrooms, and delivering handouts. Twenty-two subjects participated in the study; 14 subjects were male, and eight subjects were female. The subjects were randomly assigned to the treatment groups. Every subject completed the Informed Consent Form. Of the 14 participants in the treatment one group (black-box + no feedback), nine were male (64%) and five were female (36%); for the treatment two group (glass-box + feedback), five were male (63%) and three were female (37%).

Explanation of Simulations

Two types of the same simulation environment used in this study: black-box + no feedback simulation environment and glass-box + feedback simulation environment. Both simulation environments simulated an ecosystem of a pond located in East Tennessee. Both simulation environments were created by using Macromedia Flash and STELLA. For further information on the development of the simulation environments, please refer to Appendix A. In both simulation environments, the participants played the role of a pond manager. The participants were expected to manage the simulated pond for 15 simulated years. During their interaction with the simulation environments, they decided on different pond management issues, including the amount of fish to be harvested and the frequency of the fertilization of the pond. In this simulated pond, there were two species of fish - bass and bluegill.

The black-box + no feedback simulation environment did not have any instructional support feature. The subjects entered their inputs, and based on their inputs, they saw the results of their decisions in the beginning of the next simulated year. They did not receive any feedback during their interaction. The glass-box + feedback simulation environment included two instructional support features including the model transparency and the feedback. The users were able to reach to the underlying model by using the “Explain this!” buttons located below each input tools of the simulations. Every

“Explain this!” button provided information about that specific input. For example, when a participant clicked on “Explain this!” button located below Fertilization check box, the information regarding the effects of fertilization in the simulated ecosystem was presented. The “Explain this!” buttons were available all the time; however, clicking on one of these buttons was required to see the related information. While the model transparency feature required a users’ input, the feedback feature was automatic. Regardless of whether participants wanted to receive feedback, they obtained appropriate feedback messages based on their performance in the beginning of each simulated year. Feedback messages were triggered by some values in the simulation; therefore, the participants might have received no feedback or sometimes they might have received up to four different feedback messages each simulated year. The inputs were inactivated when a feedback message was presented.

In both simulation environments, the participants reached the output interface with a button called “Results.” Using this button, participants could minimize and maximize the output interface. Additionally, participants could reach the seining test (a sampling method used in pond management) results from the output interface. In the output interface, the following information was presented to the users; previous years’ fish harvesting amounts (in pounds) for bass and bluegill, previous years’ average fish weights for bass and bluegill. The actual amount of fish in the pond was not presented during the simulation. However, when the simulation ended the actual amounts were presented.

Both of these simulation environments had two main versions for practice and testing purpose. The practice versions included an introduction to the simulation interface, and the objectives page, as well as the simulation itself (either the black-box + no feedback simulation or the glass-box + feedback simulation). In the practice versions, there was no tracking, and the participants were able to restart the simulation as many times as they wanted. The testing versions were used for testing the participants' simulation performance. The testing versions did not include the introduction or the objectives page. The testing versions included only the simulation (either the black-box + no feedback simulation or the glass-box + feedback simulation) with tracking features. To identify and match the data, this version started with a login page, where the participants entered their gender and ID number. The participants entered their ID number before they submitted the data. The participants were allowed to run the simulation only once. The data gathered during the participants' interaction with the testing versions were sent to an online database.

Feedback Messages

The feedback feature was integrated into the glass-box + feedback simulation environment during development. The black-box + no feedback simulation environment did not have any feedback messages integrated. The feedback provided in the glass-box + feedback simulation environment was immediate. The feedback messages provided participants with diagnostic cues. The following messages were embedded into the simulation environment, and the appropriate feedback messages were displayed based on their performance in previous years, and the simulated pool's current condition. Feedback messages were created based on the recommendations given in "Managing Small Fishing Ponds and Lakes in Tennessee" booklet (Wilson, Bramlett, & Stumpf, 2000). Feedback messages listed below:

1) Bass fishing resulted in a high catch rate of relatively small fish while bluegill fishing resulted in a low catch rate of large fish... Reconsider your management strategies.
2) You did not catch any bass in the previous year. Consider catching more bass this year.
3) Bluegill fishing resulted in a high catch rate of relatively small fish while bass fishing resulted in a low catch rate of large fish... Reconsider your management strategies.
4) You did not catch any bluegill in the previous year. Consider catching more bluegill this year.
5) Impressing performance, are you sure harvesting this much will not cause any problem for the future?
6) Consider harvesting more fish!

In addition to text messages, feedback was also provided in visual format. The visual expression of a pond manager avatar changed based on the current conditions of the pond and the participants' performance.

Quality Assurance Steps

During the development of the simulations, a couple of quality assurance processes took place. As discussed in the previous chapters, simulations used in educational settings do not include all the variables due to the impossibility of capturing all variables and the insignificance of some variables in the simulated environments. At the same time, simulations should be detailed enough to represent simulated phenomena and processes. The underlying model for the simulations used in this study was created based on Managing Small Fishing Lakes and Ponds in Tennessee booklet delivered by the Tennessee Wildlife Resources Agency. To provide the subjects with both an effective simulation and enough complexity, the underlying model was discussed with a pond management expert. According to feedback received, the underlying model was modified. After the modifications, the underlying model was approved by the pond management expert.

The development of the simulations in Macromedia Flash took place after the approval of the underlying model. When the development was completed, the simulation was presented to the subject matter expert again. Based on the recommendations, the simulation interface was revised. The interface was presented to a panel of experts consisting of twelve graduate students majoring in wildlife and fisheries area. During the review process, they interacted with the practice version of the glass-box + feedback simulation environment. Each expert provided some feedback (three major things that went well and three major things that did not go well). Recommendations from the panel of experts were focused on the interface design and usability. Since none of the feedback was about the underlying model, no adjustment was made to the underlying model. Based on the feedback, required changes to the simulation interface has been done.

The final step in quality checks was getting feedback from instructional designers. Two instructional technology graduate students and I went through the simulations together. Additionally, a professional instructional technologist reviewed the simulations for instructional design; and changes were made according to their recommendations. However, none of these recommendations required major changes. Finally, the simulation environments were presented to the research committee for a review, and approved by the committee chair.

Treatments

There were four sessions of the research study. These sessions were exact replications; however, sessions took place on different days. On the first and the third sessions, the black-box + no feedback treatment was implemented; on the second and the forth sessions, the glass-box + feedback treatment was implemented. A computer lab with an Internet connection was used for the studies. Seven days before the first treatment and on the morning of the first treatment, the researcher checked all the computers in the lab. The researcher determined the computers to be used, and confirmed that the selected computers had an Internet connection and an Internet browser (Internet Explorer version 6 or later).

All participants completed the Informed Consent Form. All information collected from students remained confidential and anonymous. Sixty ID numbers were created from one to 60. Before each treatment, the participants drew an ID number from a stack of shuffled papers with ID numbers. In the first session, the ID numbers from one to 15 were given. In the second session, the ID numbers from 16 to 30 were given. On the third session, the ID numbers from 31 to 45 and on the forth session, the ID numbers from 46 to 60 were used. The separation of ID numbers allowed the researcher to define which treatment the participants took part.

A Group Embedded Figures Test (GEFT) booklet was given to each participant. Then, the participants were given the directions from the test manual for taking the Group Embedded Figures Test. Participants were asked to provide only their ID number and their gender with the booklet. They were specifically instructed not to provide their name or their birth date. Before the interaction with the simulations started, the participants' ID numbers and gender information were checked. Participants were reminded to complete absent information or to delete unneeded information. The GEFT test was conducted and graded based on the directions from the GEFT manual. The grading took place after the sessions had been completed. Following the GEFT test, the participants were provided with an introduction to the simulation environment. This introduction included basic information on the simulation interface such as the operation of input tools, how to maximize and minimize the results interface, the structure of the results page, and the seining test.

Then, the participants were given the appropriate URL based on the treatment they were assigned to browse the practice version of the simulation environment. They were informed that this interaction was for practice purpose only. The participants interacted with the simulation for 20 minutes. Afterwards, they were given the second URL to browse the testing version of the simulation. They were informed that they were able to run this simulation only once, and they were asked to manage the simulated pond for the following scenario: “Manage a pond of fish for a pond owner who wants to harvest a maximum amount of fish every year while keeping both fish species in the pond.” When the simulation was loaded, they entered their ID number, selected their gender. They were given 15 minutes maximum to complete this interaction.

Treatment One, black-box + no feedback: Treatment one took part on the first and third sessions of data gathering sessions. Fourteen participants were randomly assigned to this treatment. After the implementation of the GEFT, the participants in this group interacted with the practice version of the black-box + no feedback simulation environment for 20 minutes. Following the practice, this group interacted with the testing version of the black-box + no feedback simulation environment based on the scenario for maximum of 15 minutes. The participants’ data gathered in the testing version of the black-box + no feedback simulation environment was used to calculate their simulation performance in the black-box + no feedback simulation environments. As explained, neither the practice version nor the testing version of the black-box + no feedback simulation environment had the model transparency and the feedback features.

Treatment Two, glass-box + feedback: Treatment two took part on the second and forth sessions of data gathering sessions. Eight participants were randomly assigned to this treatment. After the implementation of the GEFT, the participants in this group first interacted with the practice version of the glass-box + feedback simulation environment for 20 minutes. Following the practice, the participants interacted with the testing version of the glass-box + feedback simulation environment based on the scenario for maximum of 15 minutes. The participants' data gathered in the testing version of the glass-box + feedback simulation environment was used to calculate their simulation performance in the glass-box + feedback simulation environments. As explained, both the practice version and the testing version of the glass-box + feedback simulation environments had the model transparency and the feedback features.

Data Collection

During the data collection, four sessions took place for the study. Each session followed the same procedures. Before each treatment, the GEFT was implemented to gather data about the subjects' cognitive style. This data was mainly used for partially answering the research questions two and three.

Additionally, the data regarding the participants' simulation performance in the simulation environments were gathered. During this process, the participants were allowed to run the simulation only once. The maximum time allotted for this interaction was 15 minutes; all of the participants were able to finish their interaction less than 15 minutes. When the subjects completed working with the simulations with tracking features, a submit button appeared on the final screen. When clicked, all gathered data (seven variables) was sent to an online database through a Perl script. Perl is a server-side programming language. The Perl script was used to connect the simulations (Macromedia Flash movies) to the online database (a text file located on the server). The following information was sent to an online database.

1) Gender

2) ID number

3) The amount of bass harvested for each simulated year

4) The average weight for bass for each simulated year

5) The amount of bluegill harvested for each simulated year

6) The average weight for bluegill for each simulated year

7) The selection for fertilization for each simulated year

Identification numbers (ID) were used to match the subjects' simulation performance to their GEFT scores, which show their degree of field independence. For each participant, the values of two variables (the amount of bass harvested for each simulated year and the amount of bluegill harvested for each simulated year) were totaled for 15 simulated years to calculate a single score that shows the participant's simulation performance. During the research, no personal information other than subjects' gender and ID was captured.

Cognitive Style Instrument

The Group Embedded Figures Test (GEFT) is used to measure the participants' FD/FI cognitive style. There are 18 possible points in the GEFT; and a person can have a score between 0 and 18. Higher GEFT scores indicate higher degrees of FI. In this study, participants' GEFT scores were used to assess their degree of field independency. To categorize the participants as FD or FI, the participants' mean GEFT score was used, which was 13.5. Seven participants (32 %) whose GEFT scores were below the mean GEFT score were categorized as FD, and 15 participants (68%) whose GEFT score were above the mean GEFT score were categorized as FI.

In the GEFT manual, the reliability estimate was reported as .82 for both men and women (Witkin et al., 2002). The reliability estimate was calculated and corrected with the Spearman-Brown formula. The manual also reported the validity of the GEFT as $r = -.82$ for men and $r = -.63$ for women; this score was determined by comparison of the GEFT scores with the EFT scores (Witkin et al., 2002).

Statistical Analysis

A descriptive statistical analysis was implemented to describe each treatment group. General assumptions for conducted parametric analysis were checked before running any statistical analysis. Additionally, descriptive statistical analyses were conducted for the GEFT results for all participants and for each treatment group.

The Independent Samples Student's *t*-Test was conducted to answer research question one. Independent Samples Students' *t*-Test was used to determine whether a statistical difference existed between two treatments in the simulation performance. To answer research question two, the Pearson Product Moment Correlation test was used. Research question two was employed to show the correlation between the GEFT score (their degree of field independency) and the participants' simulation performance. Since the literature informs about the existence of correlation between the individuals' degree of field independency and their academic achievement in some educational environments, it is important to know whether this correlation exists in simulation environments. Additionally, the correlations between the individuals' degree of field independency and their simulation performance in the two treatment groups were tested with the Pearson Product Moment Correlation test to see possible effects of the two treatments.

In order to answer the third question, a Two-Way between Groups Analysis of Variance (ANOVA) test was conducted. The results of ANOVA were used to determine the main effects of cognitive style and treatment and their interaction on the participants' simulation performance.

CHAPTER FOUR

Results

Introduction

The main purpose of this study was to investigate the interaction between the FD/FI cognitive style and two instructional support features implemented in the simulation environments to explain the possible simulation performance differences for FD and FI students. Additionally, the effects of the FD/FI cognitive style in simulation performance in simulation environments, and the effects of two instructional support features (the model transparency and the feedback) in simulation performance in simulation environments were investigated. The level of significance utilized for all statistical tests was $\alpha = 0.05$. To answer the research questions based on the methodology explained in the previous chapter, the data was gathered. This chapter presents the analysis of the data and the results. The research questions for this study are given below:

1. What are the differences in simulation performance between two groups (black-box simulation without feedback and glass-box simulation with feedback)?
2. What is the relationship between simulation performance and the subjects' degree of field independency?
    a. What is the relationship between the subjects' degree of field independency and their simulation performance in a black-box simulation with no feedback?

b. What is the relationship between the subjects' degree of field independency and their simulation performance in a glass-box simulation with feedback group?

3. How does the subjects' degree of field independency interact with two versions of simulation in order to explain their simulation performance?

Data Analysis

To answer these questions, one dependent variable (the simulation performance score), and two independent variables (the treatment and the degree of field independency) were used. Twenty-two subjects participated in this study. While 14 subjects were assigned to treatment one, using the black-box + no feedback simulation environment, eight subjects were assigned to treatment two, using the glass-box + feedback simulation environment. Of the 14 participants in the treatment one group, nine were male (64%) and five were female (36%); for the treatment two group, five were male (63%) and three were female (37%).

Prior to analyzing the data, the data set was checked for the assumptions of normality, and homogeneity of variance. When the simulation performance scores were checked for the assumption of normality based on treatment, the test of normality produced a Kolmogorov-Smirnov value of .227, $p = 0.049$, for the first treatment group. For the second group, the test of normality produced a Kolmogorov-Smirnov value of 0.322, $p = 0.015$. According to the results of these tests, the simulation performance scores were not from a normal distribution. For detailed information, see Table 1.

Table 1- Test of Normality for Simulation Performance for Treatments

Treatment	Kolmogorov-Smirnov			Shapiro-Wilk		
	D	*df*	*p*	*W*	*df*	*p*
Black-Box + No Feedback	.227	14	.049	.878	14	.055
Glass-Box + Feedback	.322	8	.015	.780	8	.018

To determine possible problems, a histogram of the simulation performance was created (Figure 1). Based on the histogram, it was obvious that there were clearly two different results embedded in one dataset. This was due to a particular aspect of the simulation. In the simulated pond, the fertilization feature was able to change availability of fish in the pond dramatically. When fertilization was not used, the maximum amount of fish that could be harvested for 15 simulated years was around 600 pounds. When this feature was activated, the available fish to harvest increased three times. To test the correctness of this claim, the participants were classified into two groups based on their decisions on the use of fertilization. The non-fertilization group consisted of participants who implemented fertilization in less than half of the 15 simulated years. The fertilization group consisted of subjects who implemented fertilization in less than half of the 15 simulated years. Then, the simulation performance scores were checked for the assumption of normality based on fertilization feature.

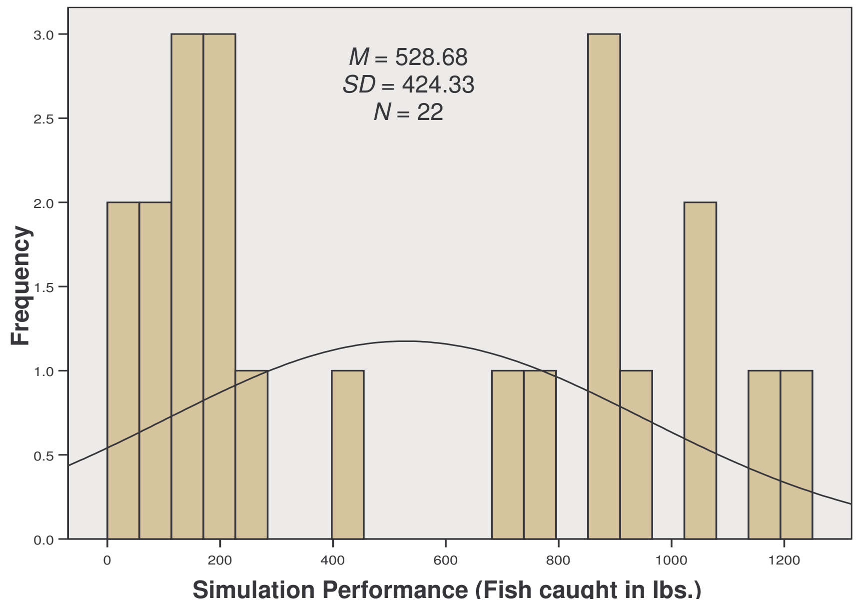

Figure 1. Histogram of simulation performance scores

The test of normality produced a Kolmogorov-Smirnov value of .220, $p = 0.20$, for non-fertilization group. For the fertilization group, the test of normality produced a Kolmogorov-Smirnov value of 0.179, $p = 0.20$. According to the results of the tests of normality, the data gathered for this study was from a normal distribution when their decisions on fertilization were considered. Figures 2 and 3 show the histogram of simulation performance scores based on fertilization groups. Presented in the Table 2 are the findings of the test of normality based on fertilization feature.

To test the assumption of homogeneity of variance, the Levene Statistic was conducted. This test of homogeneity of variance produced a Levene Statistic value of 0.004, $p = 0.953$. Based on these two tests' results, two assumptions of parametric tests were checked and no violation of these assumptions was found.

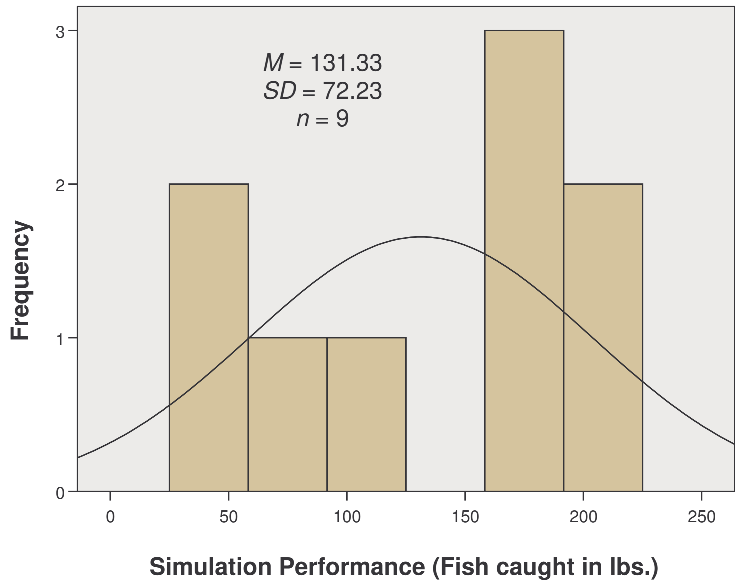

Figure 2. Histogram of simulation performance for non-fertilization group

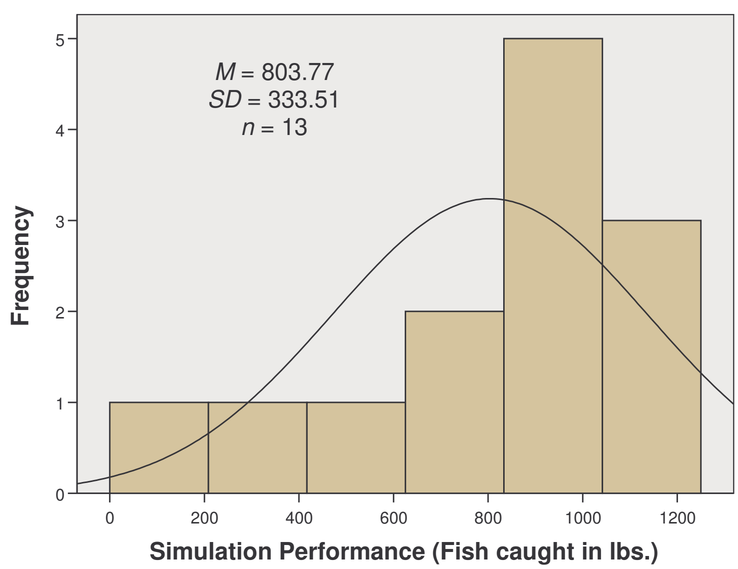

Figure 3. Histogram of simulation performance for fertilization group

Table 2 - Test of Normality for Simulation Performance based on the Use of the Fertilization Feature

Fertilization Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	D	*df*	*p*	*W*	*df*	*p*
Non-fertilization	.220	9	.200(*)	.921	9	.400
Fertilization	.179	13	.200(*)	.926	13	.299

* This is a lower bound of the true significance.

Group Embedded Figures Test Outcome

The GEFT was implemented to determine the subjects' degree of field independency. The possible range for the GEFT is between 0 and 18. While higher scores indicate higher degree of field independency, lower scores indicate lower degree of field independency (or field dependency). For this study, the participants' GEFT scores range was from 1 to 18. The mean GEFT score was 13.5 and the standard deviation was 4.98. The mean GEFT score for treatment one was 13.64 and the standard deviation was 1.24. For the treatment two, the mean score was 13.25 and the standard deviation was 2.08. Figure 4 shows the histogram of GEFT scores for participants.

To answer the third question, the mean GEFT score was used to categorize the participants as either FD (lower than 13.5 GEFT score) or FI (higher than 13.5). As a result, there were 7 (32%) FD participants and 15 (68%) FI participants. The distribution of participants based on their cognitive style is given in Table 3.

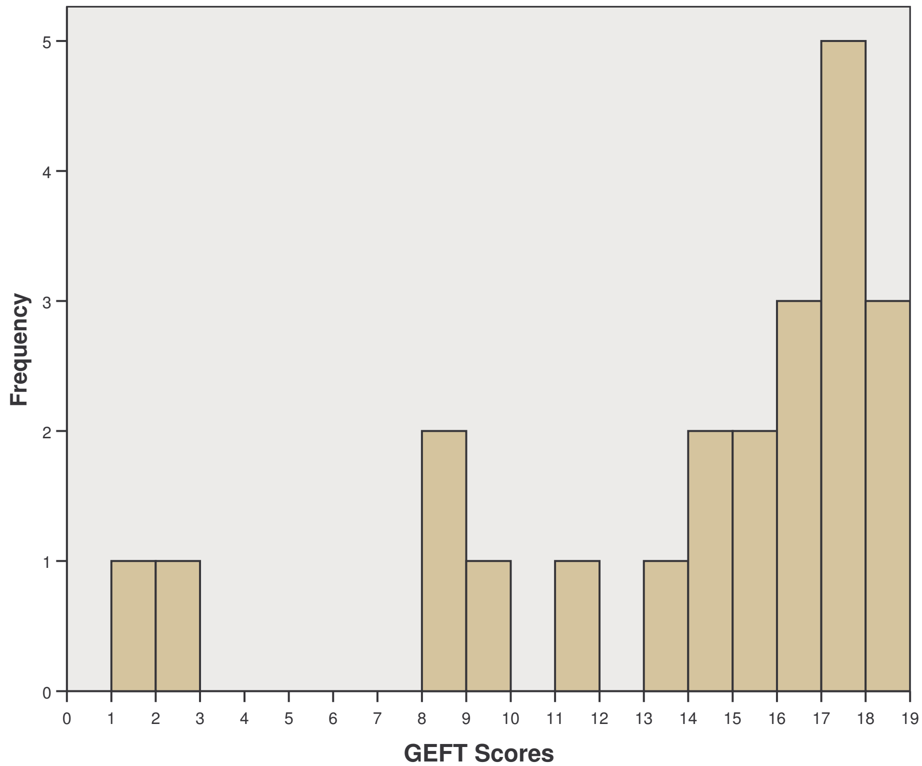

Figure 4. Histogram of GEFT scores

Table 3 - Distribution of Participants in Treatments Based on Cognitive Style

Treatments	Cognitive style	*n*
Black-Box + No Feedback	Field Dependent	5
	Field Independent	9
Glass-Box + Feedback	Field Dependent	2
	Field Independent	6

Research Questions

The results are reported within the context of the research questions posed.

Research Question 1

What are the differences in simulations performance between two groups (black-box simulation without feedback and glass-box simulation with feedback)?

Twenty-two participants were randomly assigned to one of the two treatments. After 20 minutes of practice in the practice version of the simulation environment, they were asked to manage the simulated pond for the given scenario. The scenario was "Manage a pond of fish for a pond owner who wants to harvest a maximum amount of fish every year while keeping both fish species in the pond."

For every simulated year, the participants decided on the amount of fish (both bass and bluegill) to harvest. The total amount of fish (both bass and bluegill) harvested during the 15 simulated years was totaled for every participant and this total amount was used for as participant's simulation performance. Finding revealed that the mean simulation performance value for the glass-box + feedback group (M = 396.25, SD = 454.58, $n = 8$) was lower than the mean simulation performance value for the black-box + no feedback group (M = 604.36, SD = 403.28, $n = 14$).

The Independent Samples Student's *t*-Test was performed to determine if the participants' simulation performance differed for the two treatment groups. Based on the results of this study, there was no significant difference in simulation performance between the glass-box + feedback and the black-box + no feedback groups, $t(20) = 1.113$, *p* = 0.28. Regardless of treatment, participants performed equally. The mean simulation performance value for the glass-box + feedback group was one-half standard deviation lower than the mean simulation performance value for the black-box + no feedback group ($d = -0.49$).

Research Question 2:

What is the relationship between simulation performance and the subjects' degree of field independency?

To answer this question, the Pearson Product Moment Correlation Test was conducted. Regardless of treatment, there was a low to moderate positive correlation between participants' degree of field independency and their simulation performance; however, this correlation was not statistically significant, $r = 0.396$, $p = 0.068$.

Research Question 2.a:

What is the relationship between the subjects' degree of field independency and their simulation performance in a black-box simulation with no feedback?

To answer this question, the Pearson Product Moment Correlation Test was conducted. For the black-box + no feedback group, there was a low to moderate positive correlation between participants' degree of field independency and their simulation performance; however, this correlation was not statistically significant, $r = 0.248$, $p = 0.392$.

<u>Research Question 2.b:</u>

What is the relationship between the subjects' degree of field independency and their simulation performance in a glass-box simulation with feedback group?

To answer this question, the Pearson Product Moment Correlation Test was conducted. For the glass-box + feedback group, there was a moderate positive correlation between participants' degree of field independency and their simulation performance; however, this correlation was not statistically significant, $r = 0.597$, $p = 0.118$.

Research Question 3:

How does the subjects' degree of field independency interact with two versions of simulation in order to explain their simulation performance?

The mean simulation performance value for FI participants ($M = 632.47$, SD 427.86, $n = 15$) was higher than the mean simulation performance score for FD participants ($M = 306.29$, $SD = 344.13$, $n = 7$). Based on the Independent Sample t-Test results from research question one, it was known that the treatment groups did not differ in simulation performance. However, a Two-Way between-Groups ANOVA was conducted to determine whether there was an interaction between the treatments and participants' cognitive style, and to determine whether the participants' cognitive style and treatment group influenced the participants' simulation performance. There was unequal sample distribution into these four categories; especially for cells with FD participants. However, this unequal distribution reflected the state of the population. It is known that age and educational level affect the individuals' FD/FI cognitive style. Since the participants for this study were either undergraduate or graduate students, both their age range and their educational level influenced their degree of field independency. Individuals at this age group and at this level of education tend to be more FI than FD. Due to limited sample size, it was not possible to drop some of the participants randomly from these cells. However, during the testing process, an unweighted mean approach (Type III Sums of Squares) was used. This approach was used to reduce the effects of unequal cell sizes.

Results indicated no main effect for either treatment, $F(1, 18) = 1.88$, $p = 0.187$, or the FD/FI cognitive style, $F(1, 18) = 3.58$, $p = 0.075$. There were no statistically significant differences among these groups; and there was no interaction between the treatments and the FD/FI cognitive style, $F(1, 18) = 0.11$, $p = 0.744$. Presented in Table 4 are the results. Since there was no interaction, a second Two-way between-Groups ANOVA was conducted just for the main factors. Presented in Table 5 are the results. The second test did not indicate any significant main effect for neither treatment, $F(1, 19) = 1.95$, $p = .179$, nor the FD/FI cognitive style, $F(1, 19) = 3.79$, $p = .067$. The effect size for treatment was 0.093; and for the FD/FI cognitive style, it was 0.166.

Table 4 - Two Way Between-Subjects Effects ANOVA Test for Treatment, the FD/FI Cognitive Style, and Interaction

Source	*df*	*F*
Cognitive Style	1	3.575
Treatment	1	1.884
Cognitive Style * Treatment	1	.110
Error	18	(163937)

Note: Values enclosed in parentheses represent mean square errors.

Table 5 - Two Way Between-Subjects Effects ANOVA Test for Treatment and the FD/FI Cognitive Style without Interaction

Source	*df*	*F*
Cognitive Style	1	3.787
Treatment	1	1.949
Error	19	(156261)

Note: Values enclosed in parentheses represent mean square errors.

Conclusions

This study addressed three main questions in this study. The first question concerned the effectiveness of implementing two instructional support features (the model transparency and the feedback) in simulation environments in simulation environments. According to the results of this study, participants who interacted with a glass-box simulation with feedback environment and participants who interacted with a black-box simulation with no feedback environment performed equally.

The second question concerned about the correlation between participants' degree of field independency (GEFT scores) and simulation performance. There was no statistically significant correlation between participants' degree of field independency and their simulation performance. Additionally, there was no significant correlation based on the treatments.

The final question was about the possible interaction between the FD/FI cognitive style and the treatments. According to the results, there was no interaction between the cognitive style of participants and the treatments.

CHAPTER FIVE

Discussion, Conclusions, and Recommendations

Discussion

Research Question 1:

The importance of integrating instructional support features in simulation environments was asserted by many researchers (Alessi, 2000b; Machuca, 2000; Zamora et al., 2000). One of these instructional support features was the model transparency. With the existence of model transparency, simulation becomes a glass-box simulation. Researchers suggested that glass-box simulations had a positive influence on performance (Größler et al., 2000; Lee, 1999). The results of this study do not support the conclusion that adding model transparency to simulation environments increases users' simulation performance. On the contrary, the participants in the black-box simulation environment performed better than the participants in the glass-box simulation environment did; however, this difference was not statistically significant. The following issues might explain why this study revealed a different result.

Since the diagnostic feedback feature was also implemented in addition to the model transparency feature in the glass-box simulations, it is impossible to attribute this insignificant difference only to the presence of model transparency feature. While the feedback feature was mandatory in the simulation environments used in this study, the model transparency was optional. A user's input was required to reach the description of the underlying model, while every user was subjected to the feedback feature. This mandatory interaction might have affected the simulation performance in the glass-box + feedback simulation environment negatively.

This insignificant difference might also be due to the limited complexity of the simulated environment. In this simulation, to increase its educational value and due to the characteristics of the target audience for the simulation, the underlying model was simplified. The simulations used in other studies, especially ones implemented in business management, are generally more complex. The complexity level of a simulation's underlying model might influence the effectiveness of model transparency in simulation environments. Providing transparency might influence performance positively in complex simulated environments, but not in simulation environments with a simpler underlying model.

Research Question 2, 2a, and 2b:

Previous research suggested a positive relationship between individuals' degree of field independency and their academic performance. Many research studies reported a positive relationship between the degree of field independency and achievement. However, almost every study investigated a different form of achievement. Clark et al. (2000) reported a positive relationship between GEFT scores and success performance index (high school GPA times 10 plus mACT). Cano (1999) reported a positive relationship between GEFT scores and ACT and GPA. Luk (1998b) reported a positive relationship between GEFT and course grades. However, insignificant correlations were also reported by researchers such as Garton, Spain, Lamberson, and Spiers (1999). The results of this study revealed no significant correlation between the degree of field independency (GEFT scores) and simulation performance in simulation environments. Even though in the glass-box + feedback simulation environment there was a moderate positive correlation between the GEFT scores and simulation performance, this correlation was not statistically significant. The moderate positive correlation provides a basis for further research.

The insignificant correlation might indicate that the GEFT scores do not always correlate with all the measurements of achievement. However, regardless of the treatments, the correlation between GEFT scores and simulation performance produced a *p*-value of 0.068. Even though it was still statistically insignificant, this might be caused by the limited sample size. Another study with a larger sample size is needed to conclude whether or not a significant correlation exists between GEFT scores and simulation performance in simulation environments.

Research Question 3:

Research studies about FD/FI cognitive style reported that FI individuals generally outperformed FD individuals unless the needs of FD individuals were accommodated in educational settings. The results of this study do not support the conclusion that FI students outperform FD students in educational settings. However, when the data was analyzed for the main factors, a *p*-value of 0.067 was produced in the Two-way between-Groups ANOVA for GEFT scores. Although this *p*-value is not significant, further research is needed to clarify the effect of FD/FI cognitive style on simulation performance.

In this study, FD and FI students performed equally regardless of treatments. Glass-box simulations with diagnostic feedback features do not help FD students to increase their simulation performance. Since the results of this study did not show any performance differences between FD and FI students in any simulation environments, it cannot be concluded that model transparency and feedback features can be used to accommodate the needs of FD students in simulation environments.

Summary of Discussions

In summary, the following results are concluded from this study:

1. Interacting with a glass-box simulation integrated with diagnostic feedback does not increase individuals' practical performance in a simulation environment. A black-box simulation without any diagnostic feedback can be as beneficial as a glass-box simulation integrated with diagnostic feedback for practical performance in a simulation environment.
2. There is no statistically significant correlation between individuals' degree of field independency and individuals' practical performance in a simulation environment.
3. There is no statistically significant difference in practical performance results in a simulation environment between FD and FI individuals.
4. Integrating model transparency and compulsory diagnostic feedback features in a simulation environment does not help FD or FI individuals to increase their practical performance in a simulation environment.

Conclusions

Since the results of this study showed no difference in the simulation performance of FD and FI students, it is unclear what the effects of implementing model transparency and diagnostic feedback in the simulation environments on the achievement of the FD students are. It might be concluded from these results that there is no achievement discrepancy between FD and FI students in simulation environments; however, there might be other reasons for this insignificant performance difference. Some possibilities explained in the discussion section were complexity of the underlying model and the limited sample size.

Regarding model transparency feature, the results also contradicted previous findings of the literature. Since both the feedback and the model transparency features were implemented in the study, it was not possible to conclude about the effectiveness of the model transparency.

Recommendations for Further Studies

First, it is important to note that this research was limited. The small sample size and an unequal distribution of the participants in the treatment groups might have caused some problems during the analysis. Additionally, extra caution should be paid when generalizing the results of this study to other simulations environments, because there are many types of simulations and simulation-games. This study dealt with only two types of simulation. One type was a Web-based conceptual simulation, which was implemented in discovery mode. The other type was a Web-based conceptual simulation, which was implemented in expository mode. There was only one type of assessment, and this assessment was used to assess the participants' near-transfer performance. The results were provided in text-only format in the simulation environment. As mentioned by Alessi (2000a), the results of this study are only applicable to these kinds of simulations. To generalize the results, it is important to conduct other research studies with other types of simulations with other measurement tools.

The focus of this study was the relationship between FD/FI cognitive style and simulation performance. However, other individual differences might have a role in explaining the differences in simulation performance. Especially, prior knowledge, motivation, and familiarity with simulation environments might affect the results. To explain their possible roles in simulation environments, further studies are required.

The glass-box simulation implemented in this study was created by adding transparency to an underlying model in text format. However, Alessi (2000b) discussed that there were other options to creating model transparency in simulation environments, such as system dynamics, causal loop diagrams, algebraic representation of the model, visualization by means of movies and animations of the model's elements interacting and changing. Providing the underlying model in text-only format might also explain why there was no significant performance difference between glass-box and black-box simulations. Angeli and Valanides (2004) found a significant interaction between the FD/FI cognitive style and the format of the model transparency. Angeli and Valanides reported that text only formats did not interact with the FD/FI cognitive style. However, FI students benefited from the instructional materials in text and visual format more than

FD students did in simulation environments. Therefore, the model transparency was provided in only text format in this study to control this interaction. Further studies are needed to clarify the role of the model transparency's format in users' performance. The format of the model transparency might have more influence in the simulation performance than just the presence of the model transparency in the simulation environments.

Rieber (2005) reported that there was an interaction between format of the feedback and types of performances in simulation environments. He reported the results of a series of research studies related to types of feedback and simulation performance. The types of feedback provided in these research studies were graphical feedback, textual feedback, or a combination of both graphical and textual feedback. In these studies, the learning results were evaluated with both performance assessment, and objective tests. A game-like activity in the simulation environment was used for performance assessment. A multiple-choice test of physics understanding was implemented as the objective test. Based on the results of these studies, Rieber reported that feedback in graphical form increased the objective test results, while feedback in textual form did not have any affect. However, format of feedback in simulation environments had no clear effect on performance assessment results.

In the present study, the simulation performance was measured with a performance assessment method; the participants were asked to manage the simulated pond for a certain scenario. The results of their decisions were provided in textual information, there was only one graphical element included (pond avatar in glass-box +

feedback version). As stated by Rieber (2005), providing feedback in text-based form in simulation environments had limited or no influence performance assessment results. In the glass-box + feedback version, the feedback was in text-only format and the model transparency was in textual format, even the results were provided in text-only format. While the research studies reported by Rieber did not deal with the effects of the format of the model transparency and the feedback, providing these instructional supports in text-only format might not help to increase performance assessment results either. The format of these instructional support features provided in simulation environments might influence performance assessment results and objective test results differently in simulation environments. Since there was no objective measurement implemented in this study, it was impossible to conclude and explain these issues. Further studies are required to explain these issues.

Even though it was not statistically significant, the results of this study showed that the participants in the glass-box + feedback simulation environment had lower simulation performance than the participants in the black-box + no feedback simulation environment. Even though some possible reasons for this discrepancy were discussed, there is a need for a complementary qualitative research. The results of a qualitative research might explain how participants' experience differs by the treatments. It might also provide us with deeper understanding of FD and FI students' experience in simulation environments.

Ford and Chen's (2001) investigation of the effects of matching and mismatching in Web-based instruction materials on the students' performance revealed that mismatching condition had no effect on the practical performance. Yet, they reported that mismatching conditions in these Web-based instructional materials negatively affected the conceptual knowledge gain. The results of the present study partially support these findings. However, a lack of an objective measurement tool (for measuring conceptual knowledge) prevents us from making a claim about the conceptual knowledge gain. Many research studies showed that FI students outperformed FD students in educational settings; however, this might be correct for only conceptual knowledge gain. Investigating the effects of the FD/FI cognitive style for both performance and conceptual knowledge gain may produce different results. Further studies are required to explain this issue.

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LIST OF REFERENCES

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APPENDICES

Appendix One: Development of the Simulations

Alessi (2000b) suggested a four-step process for creating simulations. The first step was to create the underlying model in a system dynamics program. The second step was to transfer this model to an authoring application. The third step was to build the simulation interface inside the authoring application. The fourth step was to build instructional support features. During the development process of these simulations, these four steps were followed. Alessi suggested that following these steps helped to reduce the development time and to increase the quality of the simulation.

In the first step, the underlying model for simulations was created by using STELLA, a system dynamics application. This same underlying model was used for both simulations. Alessi (2000b) advocated that using one of the system dynamics applications was the best starting point for creating an underlying model for a simulation, because the features of this kind of applications allowed instructional developers to create and to revise the model easily with its visual interface. Additionally, the equations defining the relationships between system units could be simply edited with an integrated equation editor. The underlying model for the simulations created by STELLA is shown in Figure 5.

The second step in creating the simulations was the transfer of the underlying model into an authoring application. Even though Alessi (2000b) suggested Macromedia Authorware, the authoring software selected for this project was Macromedia Flash. During the development of the simulation, the following procedures, explained by Alessi,

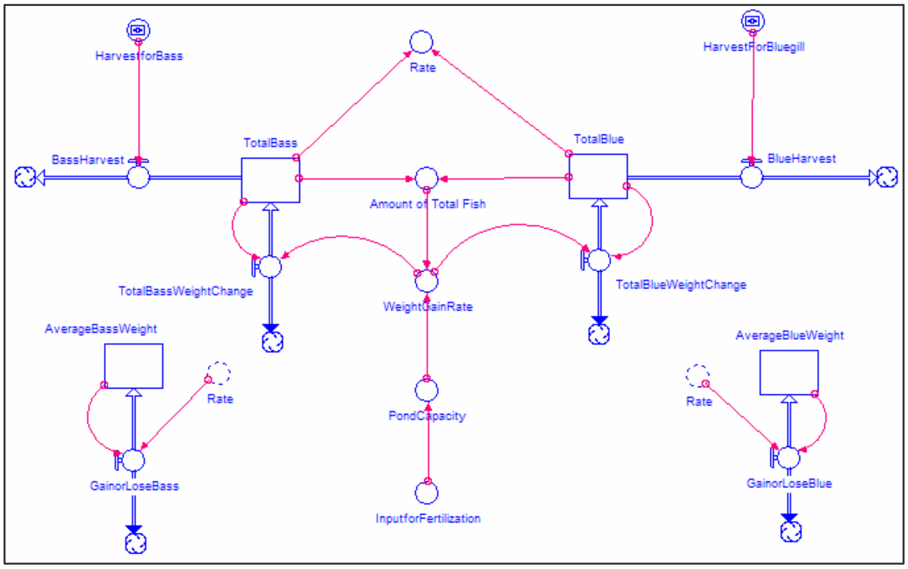

Figure 5. Underlying model of the simulation created in STELLA

was followed: arranging equations, copying the equations, building a loop, and translating equations.

The third step was the development of the interface. As discussed by Alessi (2000b), STELLA and other system dynamics applications had limited features for creating interface elements; this was not the case with Macromedia Flash. Macromedia Flash allows instructional developers to create input and output objects that are more realistic, such as rotary dials, buttons, movies, and animations. Figure 6 shows the simulation screen that displays the input and output interfaces together.

The fourth step in the simulation development process was to build instructional supports. The black-box + no feedback simulations did not integrate instructional support. However, glass-box + feedback simulations integrated two instructional support

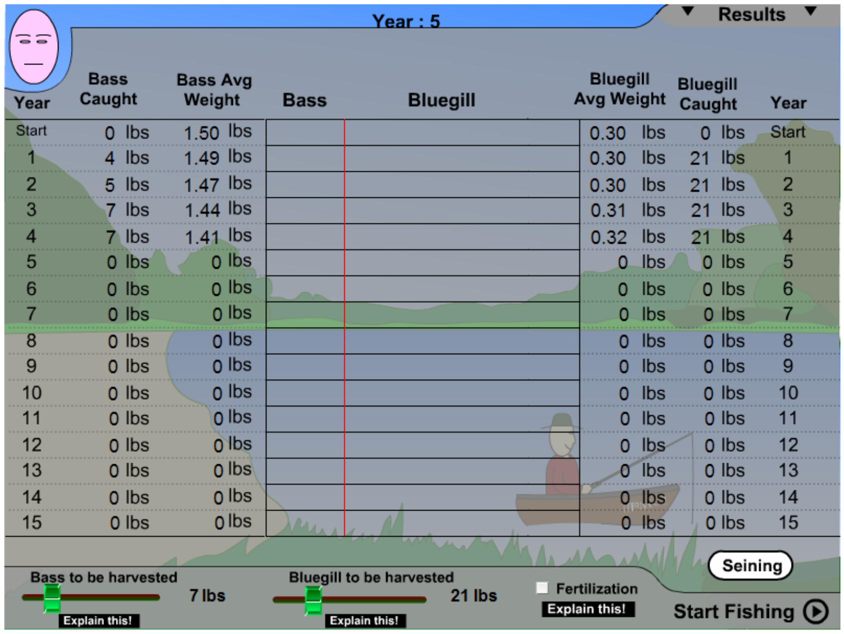

Figure 6. Input and output interface together

features. These were model transparency and feedback. The model transparency feature was implemented by using textual information about the underlying model. For the feedback feature, a pond manager avatar was used. Based on the subjects' input, the avatar presented feedback in the text form. Figure 7 shows the simulation screen that displays one of the feedback messages. Figure 8 shows the simulation screen that displays when model transparency feature is activated.

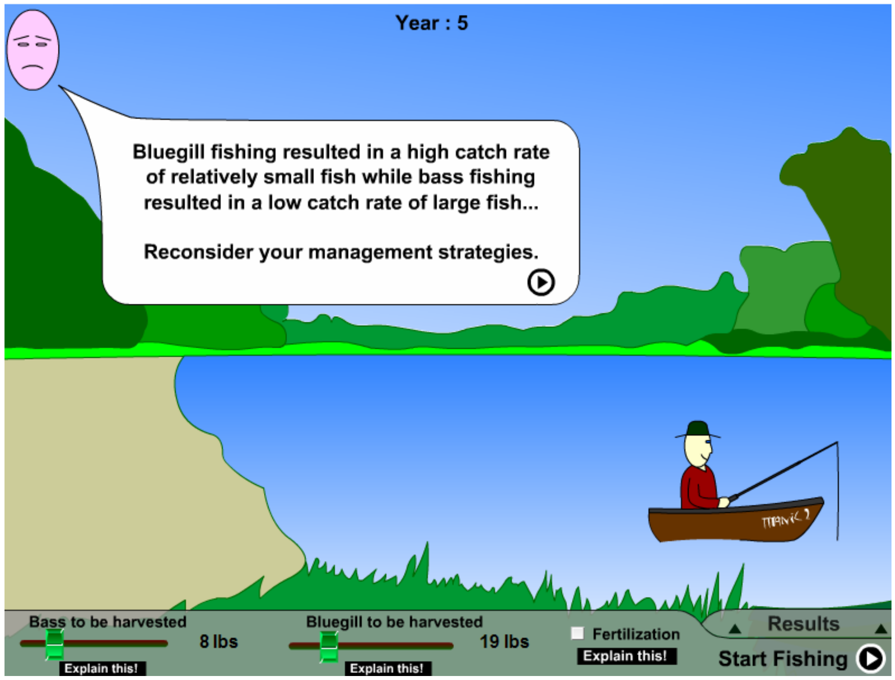

Figure 7. Simulation screen with feedback

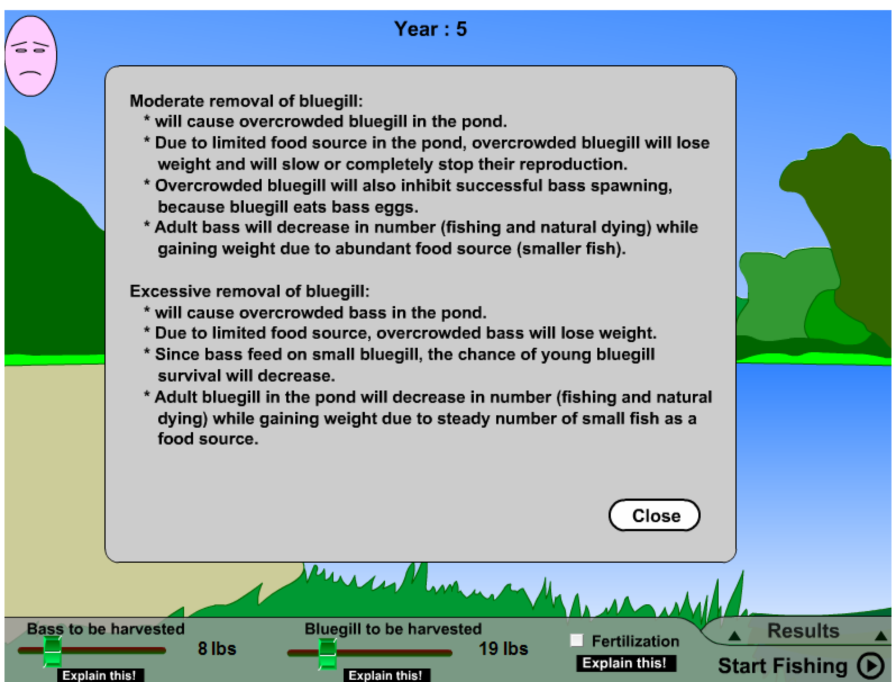

Figure 8. Simulation screen when model transparency feature is activated

Appendix Two: Informed Consent Form

Accommodation of Needs of Field Dependent Learners in Educational Simulations and Games

Introduction

You are invited to participate in a research study. You must be 18 years of age or older to participate. The expected number of participants is between 18 and 24. The purpose of this study is to examine the effectiveness of two instructional strategies on the performance of learners with various degrees of the field dependence/independence cognitive style in the simulation based learning environments. Two instructional strategies are feedback and model transparency.

Information about Participants' Involvement in the Study

If you agree to be in this study, you will be expected to complete the followings:

- Group Embedded Figures Test; around 20 minutes
- Introductory instructions for using simulation; 10 minutes
- Free form simulation use; 20 minutes
- Simulation use based on given scenario; 15 minutes

Risk of Participation

There are no anticipated risks by participating in this study.

Benefits

Your only personal benefit from being in this study is $15.00 monetary incentive in cash on the completion of all instruments. You may not benefit personally from the results of this study. The goal of this study is to contribute additional information regarding design and development of educational simulation games, and their effects on the learners' performance. The results of the study will also contribute additional information on the field dependence/independence cognitive style research.

Confidentiality

Your participation is strictly voluntary. No personal identifiable information (name, surname, email, institution, etc.) will be collected. Data will be stored securely and will be made available only to persons conducting the study unless participants specifically give permission in writing to do otherwise. Informed consent form will be stored for three years following completion of the study, other data will be destroyed at the completion of the study.

Contact

If you have questions at any time about the study or the procedures, you may contact the researcher, Ahmet F Satici, at 400 Dunford Hall #2444, phone number (865) 974-9670. If you have questions about your rights as a participant, contact the Compliance Section of the Office of Research at (865) 974-3466.

Participation

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at anytime without loss of benefits to which you are otherwise entitled. However, it will result in loss of monetary incentive. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed upon your request.

Consent

I have read the above information. I have received a copy of this form. I agree to participate in this study.

Participant's signature ______________________________________ Date _______________

Investigator's signature _____________________________________ Date _______________

VITA

Ahmet F Satici graduated from Gazi Univeristy in Turkey with a Bachelor's degree in Computer Systems Education in 1996. He served as a teacher for The Turkish Educational Ministry for two years, and taught courses in computer literacy and computer programming. He earned his Master of Science in Instructional Design, Development, and Evaluation from Syracuse University in 2001. Mr. Satici earned his Ph.D. in Education with a major in Instructional Technology from The University of Tennessee at Knoxville in August 2006.