ANALYZING THE IMPACT OF ELABORATED WORKED EXAMPLE MODELING IN A COMPUTER SIMULATION FOR PROMOTION OF SCHEMA ACQUISITION

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Worked examples have been effective in enhancing learning outcomes, especially with novice learners. Most of this research has been conducted in laboratory settings. The purpose of this study was to evaluate the impact of embedding elaborated worked example modeling in a computer simulation practice activity, within a classroom environment. The benefits derived from this study are the acquisition of empirical data that helps determine the value of embedding elaborated worked example modeling as a learning support within computer simulation activities. The data also help to determine if this is a valuable enhancement of the active learning provided by interactive computer simulations, which have already been proven effective in increasing academic achievement.
DEDICATION

To

My husband Karl,

My children, Andrew and Maricel

and

My parents, Willard and Marjorie
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I wish to express my thanks to Dr. David Brooks for never giving up on me. Through his guidance, support, and editing I was able to bring this document to completion. I wish to also thank the other members of my committee, Dr. Allen Steckelberg, Dr. David Fowler, and Dr. Charles Ansorge, for their comments and questions that always kept me thinking and learning along the way.

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# Table of Contents

LIST OF TABLES ........................................................................................................................................ vii  
LIST OF FIGURES .................................................................................................................................... viii  

I. INTRODUCTION ........................................................................................................................................ 1  
  Context of Study ........................................................................................................................................ 1  
  Purpose of Study ......................................................................................................................................... 4  
  Research Questions ................................................................................................................................. 6  
  Research Hypotheses .............................................................................................................................. 6  
  Significance of Study .............................................................................................................................. 7  

II. LITERATURE REVIEW ................................................................................................................................. 8  
  Introduction ................................................................................................................................................. 8  
  Animation .................................................................................................................................................. 11  
  Microworlds, Simulations, & Games .......................................................................................................... 11  
  Motivational Simulation/Game Environment .............................................................................................. 14  
  Mastery Learning ...................................................................................................................................... 17  
  Novice vs. Expert .................................................................................................................................. 19  
  Practice & Cognitive Load ....................................................................................................................... 20  
  Domain Transfer ..................................................................................................................................... 23  
  Worked Examples ................................................................................................................................... 24  
  Self-Explanation ..................................................................................................................................... 29  
  Cognitive Modeling ............................................................................................................................... 29  
  Summary .................................................................................................................................................. 30  

III. METHODS .................................................................................................................................................. 32  
  Introduction ............................................................................................................................................... 32  
  Population and Sample ........................................................................................................................... 32  
  Procedural Steps ...................................................................................................................................... 33  
  Variables and Measures .......................................................................................................................... 35  
  Content Validity and Reliability ............................................................................................................... 38  
  Treatments ............................................................................................................................................... 38  
  Instrument ............................................................................................................................................... 44  

IV. RESULTS ................................................................................................................................................... 52  
  Prior Knowledge Test .............................................................................................................................. 52  
  Mixed Model ANOVA ........................................................................................................................... 53
Within-subjects and Between-subjects Interaction ........................................ 54
Between-subjects Factor ................................................................................. 54
Within-subjects Factor ......................................................................................... 55
Isomorph Test ........................................................................................................ 57

V. DISCUSSION ....................................................................................................... 60
   Prior Knowledge Test ............................................................................................ 61
   Research Question 1 ............................................................................................. 62
   Research Question 2 ............................................................................................. 64
   Research Question 3 ............................................................................................. 65

VI. CONCLUSIONS ................................................................................................... 68
REFERENCES ............................................................................................................ 71
APPENDIX A ........................................................................................................... 84
   IRB Approval Document ....................................................................................... 84
APPENDIX B ........................................................................................................... 85
   Interpretation Questions ....................................................................................... 85
APPENDIX C ........................................................................................................... 86
   Archaeology Interpretation Question ...................................................................... 86
LIST OF TABLES

Table 3.01  Elaborated and non-elaborated narration examples. .......................... 36
Table 4.01  The means and percentage of accuracy (maximum score 155). .............. 53
Table 4.02  The means and standard deviations for level of accuracy. .................. 53
Table 4.03  The mean difference and effect size for each pairwise comparison. ...... 56
Table 4.04  The means and percentage of accuracy (maximum score 65). .............. 59
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.01</td>
<td>Experiment flow chart.</td>
<td>37</td>
</tr>
<tr>
<td>3.02</td>
<td>Entry page for simulations with treatment A or B.</td>
<td>39</td>
</tr>
<tr>
<td>3.03</td>
<td>Button loads narrated modeled QuickTime movie of Segment 1.</td>
<td>40</td>
</tr>
<tr>
<td>3.04</td>
<td>Button loads narrated modeled QuickTime movie of Segment 2.</td>
<td>41</td>
</tr>
<tr>
<td>3.05</td>
<td>Button loads narrated modeled QuickTime movie of Segment 3.</td>
<td>42</td>
</tr>
<tr>
<td>3.06</td>
<td>Button loads narrated modeled QuickTime movie of Segment 4.</td>
<td>43</td>
</tr>
<tr>
<td>3.07</td>
<td>Entry page with four slide choices.</td>
<td>44</td>
</tr>
<tr>
<td>3.08</td>
<td>Page where user enters Project Identification number.</td>
<td>45</td>
</tr>
<tr>
<td>3.09</td>
<td>Initial page for Segment 1.</td>
<td>46</td>
</tr>
<tr>
<td>3.10</td>
<td>Second part of Segment 1.</td>
<td>47</td>
</tr>
<tr>
<td>3.11</td>
<td>Identification of pollen types in Segment 2.</td>
<td>48</td>
</tr>
<tr>
<td>3.12</td>
<td>Computation of pollen concentrations in Segment 3.</td>
<td>49</td>
</tr>
<tr>
<td>3.13</td>
<td>Interpretation quiz in Segment 4.</td>
<td>50</td>
</tr>
<tr>
<td>4.01</td>
<td>Profile plot of the mixed model ANOVA marginal means.</td>
<td>55</td>
</tr>
<tr>
<td>4.02</td>
<td>Profile plot of the marginal means (forensic and archaeology).</td>
<td>58</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Context of Study

Science literacy is becoming more important in our complex technologically global environment. The understanding of basic scientific concepts and how to integrate them into understanding scientific information has become a critical focus for science education in the 21st century. The four key reasons for increasing science and math competency proposed by the Before It’s Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century (2000) are “...the rapid pace of change in the global economy and the workplace, the role of math and science in everyday decision making, its close ties to our national security, and its intrinsic role in shaping and defining our common life, history, and culture” (Bruning, Schraw, Norby, & Ronning, 2004, p. 338).

Problem solving ability is key to success in many domains and especially in science domains. The ability of students to acquire problem solving skills is often discussed in terms of how to provide the novice students with the metacognitive skills of the expert in a given domain. This is not saying that, by doing so, all students will become experts in that domain. Bransford, Brown, and Cocking (2000) concluded, “[R]esearchers study experts and the ways they solve problems not in the belief that every student should become an expert, but because the study of expertise shows what successful learning looks like” (Bruning et al., 2004, p. 346).

The understanding of the mechanism of cognitive load, the mental effort required to complete a task, is key to development of effective instructional design. Cognitive load
is associated with working memory. Working memory actively processes information and makes meaning out of this information. Working memory, however, is limited in how much information it can hold and process at any time (Baddeley, 1986). There are at least two types of cognitive load that working memory needs to deal with when processing information, intrinsic and extraneous. The intrinsic load is determined by the degree of interactivity between elements of the actual learning task, in other words, by the inherent properties of the to-be-learned material. Complex tasks present a high degree of interactivity, especially for novice learners and thus a high intrinsic cognitive load.

The acquisition of schema is an important part of effective learning and problem solving. “... since learning consists largely of schema acquisition, an element that needs to be learned is a schema that needs to be acquired” (Sweller, 1999, p. 28). An expert’s schema has incorporated numerous elements within a complex learning task into fewer but larger elements allowing the working memory to hold more of the information at one time. The novice learner, on the other hand, has not formed the schema for a given complex task and thus must try and process each of the multiple elements individually. This may exceed the capacity of the working memory requiring it to hold too many elements at one time and causing it to fail before the task is complete. This is referred to as cognitive overload.

Extraneous cognitive load can be introduced through the design of the instructional materials. Thus, this source of overload is somewhat controllable. Poorly designed instructional materials and/or layout of content can greatly increase the amount of extraneous cognitive load associated with a learning task; well-designed materials can reduce greatly this form of cognitive load.
In the development of instructional materials, one needs to be aware of the fact that a degree of cognitive load is always present in cognitive activities. Instructional designers must always be aware of these two forms of cognitive load while developing new educational tasks. When the educational content of the learning task has a high intrinsic cognitive load, the use of appropriate instructional design strategies can minimize the amount of extraneous cognitive load placed upon the learners. Design factors within the instructional design, unrelated to the learning content, often can be the source that imposes extraneous cognitive load and prevents schema acquisition.

Research in many well-structured domains in science (e.g., Physics, Mathematics, Computer Science) has provided learning support designs that incorporate this look at expert learning. Worked examples provide a learning support design in problem solving environments that utilize expert problem solutions for the novice learners to apprentice by. They typically include:

1. statement of problem,
2. worked solution for the problem represented in steps an expert would follow, and
3. the solution to the problem.

Utilization of learning by example is not a new idea. Research in learning by example has been a major educational theme for the past four decades. Atkinson, Derry, Renkl, and Wortham (2000) report the interest in learning-by-example paradigm for examination and description of concept formation processes was strong in the mid-1950s through the 1970s (Bourne, Goldstein, & Link, 1964; Bruner, Goodnow, & Austin, 1956; Tennyson, Wooley, & Merrill, 1972). Recent worked example research, however, varies
from the earlier learning-by-example research. More recent research focuses on how students learn schema and how experts vs. novices approach problem solving. This is in contrast to the earlier learning-by-example research that focused on presentation and sequencing of examples while facilitating concept learning. Most of the recent research has been conducted in laboratory settings. Some studies have been conducted during classroom instruction where the primary focus has been in well-structured content domains such as mathematics, physics and computer programming (Carroll, 1994; Ward & Sweller, 1990; Zhu & Simon, 1987).

Modeling, too, is described as a way of demonstrating the components that make up an expert’s method of complex procedural problem solving. Acquiring such skills is an important part of achieving self-efficacy in a domain. Meichenbaum’s (1977) proposed cognitive modeling includes six steps for effective instruction. The combination of worked examples and modeling, that includes a specific scenario worked out in steps through a modeled format, then becomes a hybrid learning support that research is suggesting needs to be studied in real classroom environments.

Purpose of Study

Computer simulation has been studied in science education (Kinzie, Strauss, & Foss, 1993; Rivers & Vockell, 1987; Roberts, Blakeslee, & Barowy, 1996; Sterling & Gray, 1991; Stockburger, 1982; Weller, 1995; White, 1984). In her meta-analysis on effectiveness of computer-based instructional simulation, Lee (1999) found that the average effect size for the practice mode of simulations was 0.54. This, however, was based upon a very small number of studies that met these three criteria:
1. Enough quantitative information was provided in order for an effect size to be calculated.

2. The study had a control or comparison group as part of its design.

3. There was no evidence of severe methodological flaws in the design.

From this she concluded: “…we have so many variables that are possibly related to the effects of simulation. It is difficult to be sure that such confounding does not exist. Therefore, it may be a dangerous decision for us to draw any firm conclusion based on the results” (Lee, 1999, p. 82). However, she proceeds to propose six possible conclusions, three of which lend themselves for consideration with this study:

1. Specific guidance in simulations seems to help students to perform better.

2. Even in practice mode, students showed a very little preference for simulations.

3. Science seems to be a subject fit for simulation type learning.

Several questions arise from these conclusions. Can the intrinsic motivation of a simulation practice be enhanced through outcome goals based in challenge and fantasy modes, authentic to the domain, without causing excessive cognitive overload in novice learners? Are procedural practice simulations effective in transfer of science concepts in varying domains that contain the same logic structure? Does the performance effect increase in a significant manner when guidance with elaborated worked example modeling is embedded within the simulation vs. simulations with guidance without the elaborated worked example modeling?
Research Questions

1. Does embedded learning support in the form of worked example modeling affect the academic performance of students?

2. Is there a significant difference between embedded modeled worked examples without elaboration and embedded worked examples with elaboration?

3. Do multiple practice simulations with embedded learning support affect academic performance within practice simulations that have the same logic structure but are set in different domains (isomorphs)?

Research Hypotheses

1. Procedural practice simulations with embedded learning support in the form of worked example modeling will provide a significant increase in the academic performance of the students.

2. Procedural practice simulations with embedded elaborated worked example modeling compared to non-elaborated worked example modeling will provide a greater significant cognitive transfer with novice learners due to reduction in cognitive load, but may produce a negative affect with more advanced learners due to lack of attention from a misconception of looking “too easy.” The advanced learner loses focus and motivation which limits the amount of ability the learner will allocate to the task, causing an under utilization of working memory (Brooks & Shell, 2006).

3. Multiple procedural practice simulations with embedded learning support can effect transfer between isomorphs, where logic is the same but the
physical context is different (different domains), but may produce a ceiling affect with more advanced learners.

Significance of Study

The use of non-traditional methods that incorporate experiential learning such as practice simulations in traditional classroom environments, has been slow to evolve in the university classroom. Gosen and Washbush (2004) report that reasons behind the minimalist efforts are “…the educator is plagued with opportunity-cost and time-use choices (Burns, Gentry, & Wolfe, 1990) as well as effectiveness concerns” (p. 271). The worked example research has shown that worked examples have been effective in enhancing learning outcomes, especially with novice learners.

The significance of this study has been to evaluate the impact of embedding elaborated worked example modeling in a computer simulation practice activity within a classroom environment. The participants used a realistic simulation environment to achieve an understanding of how science is used in solving forensic cases.

In summary, this study evaluated the effectiveness of an active learning design embedded with an elaborated learning support within an introductory forensic science class environment while holding constant as many other factors as possible. This provides instructors in forensic science and other science related domains new information upon which to make decisions about development of practice simulations with embedded learning support as part of the their curriculum instruction methods.
CHAPTER II
LITERATURE REVIEW

Introduction

Motivational literature often refers to the motivational component of instructional design as the “neglected factor” (Chan & Ahern, 1999; Keller, 1987a, 1987b; Malone, 1981a; Malone & Lepper, 1987; and Spitzer, 1996). A classic text on the systematic design of instruction (Dick & Carey, 1996), refers to the ARCS model (Keller, 1987a). The ARCS model principles are expressed as “…requirements to be met in order for people to be motivated to learn…” (Keller, 1987a, p. 1). Keller describes them as follows:

1. “The first requirement is to obtain and sustain the student’s Attention.
2. After you have gotten the student’s attention and begun to present the material, the student might ask the classic Relevance question: ‘Why do I have to study this?’
3. … you might still have less than appropriately motivated students due to too little or too much Confidence, or expectancy for success.
4. To have a continuing desire to learn, the student must have a sense of satisfaction with the process or results of the learning experience” (pp. 1-2).

Within each requirement influencing motivation, strategies are provided for use in instructional design. Keller (1987b) provides a follow up systematic process of motivational design that discusses how and how many of these strategies to incorporate in the program design. This systematic process of motivational design closely parallels
the instructional design process presented by Dick and Carey (1996). “The motivational process is similar to the traditional instructional design process and interfaces well with it” (Keller, 1987b, p. 6). Keller doesn’t provide any empirical studies to verify the model’s effectiveness, but states that it is based on the general theories of motivation and learning and that the practical use has been proven in field tests.

Other models developed to apply motivational instructional design include the Time Continuum Model (Wlodkowski, 1985) and the Supermotivation Approach (Spitzer, 1996). Six motivational components (attitude, need, stimulation, affect, competence, and reinforcement) are the key to a continuous sequential process in the Wlodkowski model. The foundation of the Supermotivation Approach is to build sufficient motivators into the activity. The motivators include action, fun, variety, choice, social interaction, error tolerance, measurement, feedback, challenge and recognition.

As one reviews the previous models, it is clear that there is overlap in what is viewed as the factors that motivate. Within the last two decades, the motivational research literature has taken much of the focus of motivational design instruction to the environment of computers especially the realm of “educational computer games.” Malone and Lepper (1987) sum up this focus by stating “our joint interest in intrinsic motivations for learning derived initially from the study of what makes computer games – even many educationally oriented computer games – so interesting and exciting for children” (p. 224). “An activity is said to be intrinsically motivated if people engage in it ‘for its own sake,’ if they do not engage in the activity in order to receive some external reward such as money or status” (Malone, 1981a, p. 335). Malone and Lepper interchangeably use fun, interesting, captivating, and enjoyable with the terms -
Malone and Lepper (1987) developed a taxonomy of intrinsic motivations for learning “… as a set of guidelines for the design of intrinsically motivating instructional environments” (p. 247). This taxonomy is divided into two major components of motivation: individual motivations and interpersonal motivations. The individual motivations factor is broken down into four kinds of intrinsic motivation subcomponents: challenge, curiosity, control and fantasy. The self-containment of intrinsic motivation can be provided through the interweaving of the individual motivation factors, but intrinsic motivation can also be attributed to three additional interpersonal motivational factors (competition, cooperation, and recognition) that involve extrinsic elements due to their dependency on other people (Malone & Lepper, 1987).

Successful learning is the goal with all modes of instruction. Motivation, especially intrinsic motivation, is one key factor associated with successful learning that is often unfamiliar to the instructional designer. If a learning activity is considered fun, intrinsic motivation will add to the success of achieving the learning goal. One can observe this learning element of fun everyday while watching small children discover their world. Once children have entered school, they start to classify learning as boring. “Many of them (school children) seem to find the instructional activities in schools to be dull and boring, and a substantial number will be quickly diagnosed as showing motivational deficits. In a variety of different settings and using a variety of measures, investigators have found that children’s reported intrinsic motivation in school to decrease steadily from at least third grade through high school” (Cordova & Lepper, 1996, p. 715).
Animation

Several research designs on the educational value of animation (one element usually represented in computer play), explored the issue of attitude of students (novice students) toward animated computer-based instruction (Lai, 2000; Nowaczk, Santos, & Patron, 1998; Szabo & Poohkay, 1996). Though most of the research produced positive attitude results, Szabo and Poohkay (1996) warn, “…animation as used in and of itself does not necessarily influence attitude scores” (p. 400). It is the aesthetics of the instruction that is the factor of influence. Nowaczyk, Santos & Patton (1998) use Clark’s (1983) argument that “[T]here is little solid evidence to support the conclusion that any specific medium has a distinct advantage over others in terms of learning benefits. …some of the reported benefits of multimedia are artificial and may be the result of novelty in the classroom” (p. 367). This does then tie into the idea that, at the very least, animation helps to gain attention to the instruction. It also can be short-lived and more detrimental than useful. Is there a way of utilizing animation that would stimulate learning and motivate students to want to spend more time as opposed to less time with an animated lesson?

Microworlds, Simulations & Games

Animation under learner control and uniquely changing based on each learner’s input, provides a wide assortment of practice strategies. This animation context, Mayer and Moreno (2002) refer to as “microworld game, a simulated version of a real situation.” Rieber (1996) describes a “microworld” as the design artifact that encompasses play. He defines a microworld as “a small, but complete, version of some domain of interest”
Its main characteristics include simple case domain presentation, the presentation is set up so the learner knows what to do in this microworld with little or no training and these same users self regulate their own learning. Simulations are often confused as being microworlds. The difference between simulations and microworlds lies within the level of fidelity to a specific domain they each possess. Simulations are specific to the content or domain and hold a high level of fidelity to the domain whereas, microworlds tend to incorporate elements that can crossover in domains. Thus, a microworld does not always hold true in a learning environment, for all users, due to differences in prior knowledge. However, simulations and games can be beneficial elements in a microworld. Rieber (1996) states, “[S]imulations offer a direct link to the subject matter or content; and games offer a practical means for meeting the microworld assumption of self-regulation” (p. 49). Simulations have been used for modeling scientific concepts and systems for research as well as for modeling scientific concepts and systems for educational purposes. They are often used in educational situations for training or developing a deeper understanding of a process through interactivity and practice. Christopher and Smith (1987) found that there is not a consistent term used in the literature for simulations. Simulation games, structured experiences, structured role-play, and to a certain extent behavior rehearsals are all terms used to describe the use of simulations for learning. Simulation has been defined “…as an intermediate stage between theoretical instruction (which has obvious limitations) and the real thing (which is too costly or too dangerous to be attempted)” (Leigh & Spindler, 2004, p. 51). If one changes the animated presentation of direct information to a form of a practice strategy, the educational power of animation is revealed. The most powerful form of animation in
an instructional environment seems to be represented in interactive dynamic practice or simulated practice. Animation under learner control and uniquely changing based on each learner’s input provides a wide assortment of practice strategies. Initial research on the effects of computer practice strategies on factual and application learning in elementary science provided no support for positive interaction (Rieber, 1989). Follow up research (Rieber, 1991) has shown that, with elementary-aged children, the use of interactive dynamic practice greatly enhanced their motivation for continued interaction with the activity in addition to them out performing no-practice students. Also, interactive dynamic practice improved adult encoding and retrieval tasks (Rieber, 1990b). Rieber (1990a) does warn that, when designers develop interactive practice activities, they must be aware of the fact that the novice learner may not understand the graphic feedback format that is utilized. Thus, coaching or other types of prompts may be needed to successfully overcome this perceptual problem. The ability to have no time restriction on use of interactive dynamic practice has also proven to enhance better learning (Clancy, Stasko, Guzdial, Fincher, & Dale, 2001).

Simulated practice, however, provided just for the sake of including an interactive format, doesn’t necessarily enhance the ability to reach the learning goals set for the topic. Peters, Vissers, and Heijne (1998) propose that, when a simulation/gaming approach is used in teaching, the teacher and the designer must have a known desired output and a measurement for assessment of this output. What is to be learned and the skills to learn this knowledge must be clear within the simulation/gaming environment. “If the knowledge and the skills have to be applied directly in reality, the game environment should have a strong resemblance with that reality” (Peters, Vissers, &
Heijne, 1998, p. 26). They feel that, when using simulations/gaming for educational purposes, the validity of the outcome is that the participants demonstrate that the learning objectives have been met. One can assess that the knowledge has been acquired by testing the students’ knowledge in novel environments and problems through a simulation/game environment. Greenblat (1973) classified the educational effectiveness of simulations into six categories:

1. Motivation and interest,
2. Cognitive learning,
3. Changes in the character of later course work,
4. Affective learning concerning subject matter,
5. General affective learning,
6. Changes in classroom structures and relations.

**Motivational Simulation/Game Environment**

One can also look at another beneficial aspect of the simulation/game environment for learning – motivation of the student to return to the use of the simulation/game without being directed to do so. Motivational researchers have developed multiple checklists, tables, and taxonomies for the use of motivational/instructional design. If one looks at, challenge, curiosity, control and fantasy, the four primary characteristics of intrinsic motivational learning environments proposed by Malone and Lepper (1987), “[G]ames represent the instructional artifact most closely matching these characteristics” (Rieber, 1996, p. 50). The Flow Theory, proposed by Csikszentmihalyi (1990), is the level of intrinsic motivation that a motivational/instructional designer might strive for in their simulation/game
environment. “Flow” is defined as “… the state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will do it even at great cost, for the sheer sake of doing it” (Csikszentmihalyi, 1990, p. 4). Rieber (1996) describes flow as being derived “…from activities that provide enjoyment (as compared to mere pleasure). Enjoyment results when an activity meets one or more of the following eight components:

1. Challenge is optimized;
2. Attention is completely absorbed in the activity;
3. The activity has clear goals;
4. The activity provides clear and consistent feedback as to whether one is reaching the goals;
5. The activity is so absorbing that it frees the individual, at least temporarily, from other worries and frustrations;
6. The individual feels completely in control of the activity;
7. All feelings of self-consciousness disappear; and
8. Time is transformed during the activity (e.g. hours pass without noticing)” (p. 48).

When one contemplates the first component, the reality is that the challenge within the simulation/game environment must always be changing in order to keep up with the increase in abilities by the participant. Thus, not only must the animation be dynamic in nature but the simulation/game environment must be also. “When games are applied …, the basic assumption is that we are able to translate acquired knowledge and experiences from one system to another (game to reality)” (Peters et al., 1998, p. 22).
This then becomes a primary goal of the challenge, the ability to apply the knowledge and skills of the simulation/gaming environment to novel situations that represent the real reference system that the environment is based on. As was previously mentioned, this can be accomplished within the simulation/game environment relatively easily, so the real issue becomes assessing the students in real world situations not computer simulated ones as the definitive assessment tool. Habgood, Ainsworth, and Benford (2005) however, warn that a flow state might possibly inhibit metacognition and thus hinder acquisition of declarative knowledge. They state “…few manage to make the learning content part of the flow experience” (p. 492). Brooks and Shell (2006) state, “[T]he characteristic of experiencing flow, of working the zone, is that working memory is fully occupied. There is no need to prod the process along with self-talk or questioning” (p. ?). One has to ask the question, if the learner is not incorporating the content into the flow experience, how can learning occur if all of working memory is occupied, leaving no working memory capacity available to teacher (or computer) input or self-regulation? Thus, the representations within the simulation/game should be the focus for supporting learning and not the acquisition of a state of flow. “Research with visual representations that involve explicit geometric and topological information has shown that they allow learners to benefit from powerful perceptual inferences and reduce the amount of effort required to solve problems (Simon & Larkin, 1987; Zhang, 1997). Visual representations can support the construction of mental models, which is particularly important when learning about complex subject matter (Schnotz & Bannert, 2003). Visual representations can also enhance learners’ metacognitive strategies, encouraging them to make more productive use of materials and to learn complex topics more completely (Ainsworth & Loizou,
Through employing visual representations in environments such as Microworlds and Simulations (de Jong & van Joolingen, 1998; Papert, 1980), learners can be encouraged to participate in interactive explorations of learning content (Miller, Lehman, & Koedinger, 1999; Papert & Talcott, 1997) and the links between these approaches and those employed by digital games are evident (Rieber, 1996)” (Habgood et al., 2005, p. 494). Chan and Ahern (1999) suggest that multimedia (games) presentations are a double-edged sword for instructional designers. “[W]hen the content relevance of material is high and adequate challenge is already provided to students, high presentation elements can be distracting” (Chan & Ahern, 1999, pp. 160-161). Their recommendations include using multimedia elements gradually, incorporating them primarily when challenges within the content are reduced. They go further and propose, “[W]hen the content relevance is low and inadequate challenge is provided to students, high-presentation quality has a positive effect on motivation” (Chan & Ahern, 1999, p. 161). The connection of cognitive overload to a decrease in intrinsic motivation in computer-based instruction/game scenarios presents a linear model that motivational and instructional designers need to stay aware of.

**Mastery Learning**

In addition to the motivation of the design, instructional simulations/gaming environments can help develop mastery learning, especially in science topics. Gentile and Lalley (2003) state that the science standards are guided by four principles:

1. “Science is for all students.
2. Learning science is an active process.
3. School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.

4. Improving science education is part of systematic education reform (NRC, 1996, pp. 20-21)” (pp. 44-45).

They emphasize the National Research Council’s (NRC) focus on the importance of inquiry based learning and understanding and integration of scientific content over just learning the facts in teaching science. “Inquiry into authentic questions, generated from student experiences, is the central strategy for teaching science” (National Research Council, 1996, p. 31). The content standards are explicit in providing less emphasis on vocabulary, facts, and information in favor of understanding and integrating scientific content (e.g., NRC, 1996, p. 113)” (Gentile & Lalley, 2003, p. 46). If one analyzes the issues raised by the four principles of the Science Standards in reference to mastery learning, one finds that “[M]astery learning is directly concerned with all of the following issues raised by the Science Standards:

1. Identify the objectives.

2. Assess what the students already know or can do regarding those objectives.

3. Invent exercises so that the students may not only acquire knowledge but also organize and use that knowledge to acquire more knowledge, solve problems, and test hypotheses.

4. Assess in ways consistent with the above to ensure that all students receive feedback and are at least minimally competent vis-à-vis those objectives.
5. Devise exercises and follow-up assessments to remediate students who at first fail to achieve minimum acceptable performances.

6. Create a grading system and exercises designed to entice students to go beyond competence and work toward true expertise (via peer tutoring, advanced projects, etc.)” (Gentile & Lalley, 2003, pp. 53-54).

Novice vs. Expert

The issue of inventing exercises so that the students may not only acquire knowledge but also organize and use that knowledge to acquire more knowledge, solve problems, and test hypotheses seems perfect for utilizing simulation practice. A simulation practice activity has a built-in follow-up assessment in the form of multiple performance opportunities with feedback that can be utilized to help remediate the students who initially fail in their performance of the activity. However, the question that arises at this point is how can the practice accommodate multiple levels of user prior knowledge so that a user’s motivation stays high? Computer games utilize ascending levels to accommodate mastery of skills and information allowing for their value in developing user self-regulation. Simulation practice activities, however, are not usually designed with this gaming element. So how can the novice, as well as the more advanced student, acquire expert methods of problem solving and develop the domain schema for successful transfer of content concepts and principles through simulation use? To proceed in finding some possible solutions to this question one must review the differences between how experts approach solving problems with the way in which a novice would approach solving the same problems. Major differences between experts and novices include:
1. Experts organize domain knowledge around the big ideas and core concepts of that domain.

2. Experts use a working-forward (means-ends) strategy approach, while a novice may use a working-backward strategy.

3. Experts have the ability to recognize meaningful patterns of information. This is done through their ability to chunk information and organize the information into schema.

4. In science domains, research has shown experts using ‘qualitative analysis’ (Larkin, 1977) or ‘physical intuition’ (Simon & Simon, 1978). This trait allows the expert to develop elaborate representations of the problem, including a sketch or other types of physical versions of the problem.

5. Experts possess more domain knowledge than novices and are able to more efficiently search their database of information for the problem and the retrieval of the necessary information is acquired in a more fluent manner. This then causes a minimal amount if any cognitive load, allowing for more focus to be placed on more demanding parts of the problem.

6. Experts possess more procedural knowledge than novices (Bruning et al., 2004).

Practice and Cognitive Load

Research studies conducted by Ericsson (1996) and Ericsson, Krampe, and Tesch-Romer (1993) have shown that “[S]kill development and expertise are strongly related to
the time and efficiency of deliberate practice. The more one practices, the better one
gets regardless of initial talent and ability” (Bruning et al., 2004, p. 177). Is it this simple?
Can just copious amounts of practice develop a novice into an expert? Not if the learning
design within the practice activity contains elements that create cognitive overload within
the novice’s working memory. Mayer and Moreno (2003) have conducted research
studies that have suggested nine effective ways to reduce cognitive overload in
multimedia learning. The research effects for better transfer are as follows:

1. Modality effect – presenting words as narration in place of onscreen text.
   Effect size = 1.17

2. Segmentation effect – lesson segments are set-up for learner control as opposed to a continuous presentation. Effect size = 1.36

3. Pretraining effect – names and behaviors of the system components are known by the user. Effect size = 1.00

4. Coherence effect – extraneous material is eliminated. Effect size = 0.90

5. Signaling effect – signals are included. Effect size = 0.74

6. Spatial contiguity effect – printed words are placed near corresponding graphics. Effect size = 0.48

7. Redundancy effect – narration is exclusively used to represent words as opposed to using narration and onscreen text. Effect size = 0.69

8. Temporal contiguity effect – animation and narration are presented together. Effect size = 1.30

Clear evidence of high reduction of cognitive load would be evident in multimedia design incorporating elements that foster these nine effects. Reduction of extraneous cognitive load or that part of cognitive load that does not contribute to learning is essential. But Sweller’s cognitive load theory (Sweller, 1988) also proposes another characteristic for efficient training. This characteristic is the maximizing of the portion of the load that does contribute to learning. This characteristic is referred to as the germane cognitive load (Sweller, van Merriënboer, & Paas, 1998). Germane cognitive load is where cognitive schema develop. However, schema development takes an intense amount of mental activity. “The heavy cognitive load of schema induction, however, pays off at the latest when transfer tasks have to be solved on the basis of the knowledge acquired” (Stark, Mandl, Gruber, & Renkl, 2002, p. 43). Once acquired, these schema are what reduce the amount of working memory capacity needed to problem solve within a specific domain.

Transfer of schema knowledge to novel problems within the same domain is referred to as near transfer. This type of transfer involves problem solving where only the surface structure of the problem differs. Far transfer on the other hand, refers to transfer of schema knowledge to novel problems within other domains. Far transfer requires the ability to analyze and deal with both surface and deep structural differences from problems encountered in the original domain. The deep structural aspects of a problem have been shown through research (e.g., Chi, Feltovich, & Glaser, 1981; Chi, Glaser, &
Rees, 1982; Silver, 1979) to be the focus of experts while novices tend to focus only on the surface structure (Atkinson, Derry, Renkl, & Wortham, 2000).

**Domain Transfer**

In order to achieve effective near and far transfer of domain schema, the novice learner has to acquire:

1. More domain knowledge and the ability to search it efficiently.
2. More domain procedural knowledge.
3. An ability to organize both the domain knowledge and procedural knowledge around the big ideas and core concepts of the domain.
4. An ability to chunk and organize the information into schema so they can easily recognize patterns.
5. An ability to use a working-forward (means-ends) strategy approach in solving problems.
6. Development of ‘qualitative analysis’ or ‘physical intuition’ in science domains.

The instructional designer must then utilize learning supports that can help in development of effective transfer. Research has shown that “[L]earning supports, either embedded within simulation software or provided by human tutors in classroom settings, should be directed towards all three perspectives:

1. Interpretive support: helping learners with knowledge access and activation, the generation of appropriate hypotheses, and the construction of coherent understandings;
2. Experimental support: scaffolding learners in the systematic and logical
design of scientific experiments, the prediction and observation of
outcomes, and the drawing of reasonable conclusions; and

3. Reflective support: increasing learners’ self-awareness of the learning
processes and prompting their reflective abstraction and integration of
their discoveries to invite meaningful, systematic, and reflective discovery
learning with computer simulations” (Zhang, Chen, Sun, & Reid, 2004,
p. 280).

Worked Examples

Caution must be exercised when revisiting the suggestion that, the more one
practices, the better one gets regardless of initial talent and ability with application to the
learning support of simulation practice. Traditional practice-based problem solving has
been found to be “…less than an ideal method for improving problem-solving
performance when compared to instruction that paired practice problems with worked
183). Worked examples are a form of learning support that research has shown to be very
effective in initial acquisition of cognitive skills for novices in well-structured domains
such as mathematics, physics, and computer programming (Renkl, 1997; Renkl, 2002;
Stark, Mandl, Gruber, Renkl, 2002; van Gog, Paas, & van Merriënboer, 2004). It has also
been found that novices tend to prefer this type of learning support.

The Atkinson et al. (2000) worked example review, proposes instructional
principles derived from the worked example research that moderate their effectiveness.
The three principles are:
1. “Intra-example features, in other words, how the example is designed, particularly the way the example’s solution is presented.

2. Inter-example features, principally certain relationships among multiple examples and practice problems within a lesson.

3. Individual differences in example processing on the part of students, especially the way in which students “self explain” the examples” (p. 186).

The first principle integrates many of the cognitive load reduction factors that have been previously discussed in relationship to Mayer and Moreno’s (2003) nine ways of reducing cognitive load in multimedia learning. Jeung, Chandler, and Sweller’s (1997) research study in geometry, utilized worked examples incorporating the temporal contiguity effect (an audio-visual condition) that also included the signaling effect in the form of visual cues directing the learner’s attention to the part of the diagram being discussed in the narration. “According to Jeung et al. (1997), simply adding electronic flashing to a dual-mode example can lead to enhanced learning, even under high-search conditions, by encouraging the learner to devote cognitive resources to understanding the example, as opposed to dedicating them to search and recognition” (Atkinson et al., 2000, p. 189). Chandler and Chaillé (1993) had also hypothesized that within computer simulations “…process highlighters promote awareness of the underlying principles and mechanisms at work in a given situation” (p. 242). Their research tentatively verified this hypothesis, but they stress that future research needs to “…help clarify issues concerning transfer of knowledge and the effectiveness of different types of process highlighters, as well as applicability to a broader range of problems” (p. 261). Catrambone (1994a,
1994b, 1995, 1996), as reported in Atkinson et al. (2000), determined that two techniques (labels and visual separation of steps) designed to accentuate the sub-goals of an example, were most efficient in performance enhancement. Again, two of the Mayer-Moreno load reduction effects, segmentation and special contiguity, have been shown to be effective in this research.

Research that has focused on inter-example features of the lesson design, propose four issues for discussion:

1. How many examples should be presented during the instruction?
2. Should the examples vary and, if so, how should they vary within the lesson?
3. How can the “surface stories” be varied to enhance the instruction?
4. How should the worked examples be mixed in with the practice?

Though most worked example researchers propose that it is necessary for multiple examples to be presented when students are learning complex concepts (e.g., Cooper & Sweller, 1987; Gick & Holyoak, 1983; Reed, 1993; Spiro, Feltovich, Coulson, & Anderson, 1989; Sweller & Cooper, 1985), a direct study of the question; “Can one example facilitate learning?” was done by Reed and Bolstad (1991). Their prediction, however, was that there is a need for at least two (one simple and one complex) examples to effectively facilitate learning of complex concepts. According to their conclusions, their prediction of one simple and one complex example being sufficient to accomplish both near and far transfer was shown to hold true. However, Ahn, Brewer, and Mooney (1992) concluded from their research results, using an explanation-based learning
approach on concept formation, that “[H]uman learners can acquire a schema from a single example in knowledge-rich domains, but not in knowledge-poor domains” (p. 391). Renkl (1997) found that multiple examples were not necessary when near transfer was the goal of the learned knowledge. It seems to be of importance for far transfer. Renkl, Stark, Gruber, and Mandl (1998) state that results from their previous studies (Stark, Graf, Renkl, Gruber, & Mandl, 1995) found multiple examples without supported learning equates to poor performance. One must bear in mind that when presenting worked examples as part of instruction, “[T]he number of examples that can be used for teaching a particular idea may be constrained in practice by such issues as instructional time and problem complexity, since teachers often cannot present many complex examples” (Atkinson et al., 2000, p. 202).

If one chooses to present multiple examples, research by Paas and van Merriënboer (1994) suggests that variability of the examples produced transfer benefits, but in situations where practice is not supported by cognitive load reduction such as instruction utilizing worked examples, variability does not provide a significant benefit. Quilici and Mayer (1996) conducted several studies that examined structure-emphasis compared to surface-emphasis in worked examples. The structure emphasizing techniques were found to be more effective in enhancing learning and they demonstrate that only looking at surface features of a problem is not effective. This ties back to an earlier stated key difference in how an expert works through problem solving compared to novices, namely, the expert analyzes the deep structure of a problem where a novice can become caught up in only focusing on the surface structure. This research has also shown that utilization of only a fixed number of cover stories across various problem
types is preferable in novice learning. In addition to this finding, additional studies report that variability of worked examples is not to be recommended due to producing an overloading condition for the users (Renkl et al., 1998).

Mixing worked examples in with the practice raises the question as to whether or not worked examples pairing with practice problems, typically the presentation format, is the most effective sequencing. Based upon findings by Trafton and Reiser (1993), the assertion is made that “[T]he most efficient way to present material to acquire a skill is to present an example, then a similar problem to solve immediately following” (p. 1022). These pairing of worked examples and practice problems should also be interspersed throughout the instruction as opposed to presenting a block of worked examples and then a block of practice problems. The studies on preinstructional simulations (Brant, Hooper, & Sugrue, 1991; Hargrave, & Kenton, 2000) may present a unique sequencing proposal for the issue of interspersion of the worked example paired with practice problems. What if the introduction of a pair of worked examples and practice problems was provided to the students before the formal lecture information was presented? Would this instill motivation on the part of the students to ask more informed questions during the lectures on those parts of the concepts being presented that didn’t make sense? Would the worked example and practice problem need to be formatted into a computer simulation, giving the student an initial contextual domain base? Brant et al. (1991) argue “…the student is better prepared to connect theoretical information to situations where its application will lead to a more accurate prediction of inheritance” (p. 478). Hargrave and Kenton (2000) echo this idea and imply that in science education the student can “(a) explore science phenomenon under appropriate contextual conditions, (b) test their ideas and develop
their understanding of the concepts (c) develop an interest in the topic, and (d) generate questions” (p. 53) if given the opportunity to use simulations prior to instruction.

Self-Explanation

Students who can effectively self-explain how to problem solve perform well above those who do not. The novice learner is often at a loss with this strategy, especially through the working-backward strategy commonly used in problem solving. How can instruction, in the form of practice, foster effective self-explanations? Studies suggest that direct training of self-explanation in addition to the presence of sub-goal labels and incomplete example formats effectively enhance self-explanation ability in learners. Would this enhance the learner’s ability to effectively achieve transfer? For learners with deficits in prior knowledge and motivation (the novice learner) Stark, Mandl, Gruber, and Renkl (1999) state that “[L]earners should always have access to modeled example elaborations and, if necessary, to additional information which could be relevant to problem solution as well as to complete understanding of the solution step” (p. 606).

Cognitive Modeling

Modeling, an important component in developing self efficacy in any domain, has been proposed by Bandura (1997) to help motivate learning by raising the expectations of the learner to where they feel a mastery level is achievable. This is accomplished through obtaining significant amounts of information about how a skill is performed by an expert (Bruning et al. 2004). This can go hand in hand with Rieber’s (1996) conclusion based on research by Brown, Collins, and Duguid, (1989) and Choi and Hannafin (1995) that anchoring learning in authentic situations is effective. Modeling within simulations of authentic problem solving, provides guidance within the experiential learning
environment. Leigh and Spindler (2004) state “…experiential learning positions the educator in a supportive role and locates the learner at the center of the process. From this position, the educator helps identify opportunities for learning, engages the learner in dialogue with these, and relinquishes authority to direct the learning process” (p. 53).

This now suggests that simulations can take on a role in a novice user’s self-regulation in problem solving, an ability deemed more closely tied with expert problem solving. It is the “expert” model, however, that is key to this concept. Meichenbaum (1977) has proposed that cognitive modeling is the most effective way to adequately model a complex procedure. The steps involved in cognitive modeling include:

1. “Create a rationale for the new learning skill.
2. Model the procedure in its entirety while the students observe.
3. Model component parts of the task.
4. Allow students to practice component steps under teacher guidance.
5. Allow students to practice the entire procedure under teacher guidance.
6. Have the student engage in self-directed performance of the task”

(Bruning et al., 2004, pp. 116-117).

**Summary**

It would seem only logical that principles taken from worked-example research need to be applied to practice simulations developed for and utilized in actual class environments in order to determine if there is significant improvement in novice performance. This would correspond with a recommendation for continued research in worked examples by Atkinson et al. (2000). “Because the worked-example research has been conducted largely in controlled settings with relatively simple problems, it would be
easy for researchers who support authentic instructional paradigms to overlook or ignore findings from this literature” (Atkinson et al., 2000, p. 207). They also state that “[W]hether or not the application of these principles can significantly enhance student learning in authentic problem-solving contexts, as it has in laboratory ones, is a question that worked examples researchers should now attempt to answer in partnership with classroom researchers and practitioners” (p. 208). Having an expert think out-loud through the problem solving process may help in achieving this goal (Atkinson et al., 2004). van Gog et al. (2004) champion this idea. They argue that worked example instruction needs to take a process approach, not only providing the “how” from the product approach but including the “why” behind the rationale of the steps of the worked example. “…the expert “why” and “how” information could also be very helpful in fostering students’ understanding in less structured domains, because for tasks in these domains the goal state is not always well defined, and multiple paths might lead to an acceptable solution” (van Gog et al., 2004, p. 96).

Transfer of learning is the final factor one needs to consider in schema acquisition. Perkins (1992) states “[T]ransfer of learning occurs when learning in one context enhances (positive transfer) or undermines (negative transfer) a relative performance in another context.” (p. 2).
CHAPTER III
METHODS

Introduction

The context of an authentic forensic case was chosen as the motivational format of the simulation instrument used in this study. Each student was assigned the role of forensic palynologist on a crime scene investigation. Using the computer interactive simulations developed for this study, each student gathered pollen data. The students incorporated these data with other crime scene evidence to support a working hypothesis on “where the victim was killed” and “where the body mummified.” Four pollen simulations representing the real samples that were collected from this crime scene were the “samples” the students used to collect the pollen data. The students’ input into the simulations provided the data collected for this study.

Population and Sample

The population of this sample included undergraduate students enrolled in an introductory forensic science course. This population started with a sample of 50 students attending a large mid-western university during the 2006 fall semester. Due to participation dropout and random php upload error, the final population for this study was 39. Demographic information included an age range of 19 – 47; 25 seniors, 11 juniors, and 3 sophomores. Of the 39 students, 19 were female and 20 were male. The students’ majors represented 10 science and 29 non-science categories.
Procedural Steps

This study was conducted as follows:

1. The course instructors were asked permission to use the course for the study.
2. The IRB approval was obtained (Appendix A).
3. Advisement by dissertation committee.
4. The instructor randomly assigned to each student a project identification number during the first class period.
5. The students registered for use of the computer site at the beginning of the last class period during the fifth week of class. They then worked through a simulation that only had written label cues for progressing through the site (the prior knowledge test). Every student did the same simulation.
6. The lectures on pollen analysis in forensic science were given during the sixth week of class. Handouts consisting of two sheets of pollen identification pictures and information were given to each student to use in place of a pollen key in the simulations. The handouts were used due to class time constraints. The students were instructed to review the pollen types before attending the second and third computer class. An additional pollen ID sheet was distributed to all of the students at the beginning of the second computer class period with the statement that forensic palynologists continue to learn new pollen types.
7. A written reminder of class relocation to the computer lab was distributed in the class period two days prior to the computer class periods. A verbal reminder was given in the class before the relocation happened.

8. The second and third computer class sessions directly followed the lectures on pollen.

  • As the students arrived at the computer lab for the second computer class session, the instructor randomly assigned them either to group ID AB (treatment A - simulation with embedded modeled worked example with elaboration, was given first, followed by treatment B - simulation with embedded modeled worked example without elaboration) or group ID BA (treatment B was given first, followed by treatment A). The session then began with all of the students working through a simulation similar to the prior knowledge simulation. This was the pretest simulation. The data from the pretest simulation were analyzed for instrument reliability. Following the pretest, the students worked through the treatment condition that corresponded to the first letter in their group ID. Group AB worked through treatment A - simulation with embedded modeled worked example with elaboration while Group BA worked through treatment B - simulation with embedded modeled worked example without elaboration. A different pollen assemblage slide simulation was used with each treatment. The same simulation test (posttest #1)
followed both of the treatments. This simulation test was the same one that was used for the pretest.

• At the beginning of the final computer class session, each group worked through the treatment condition simulation that they had not done during the prior class period. Again, the posttest simulation (posttest #2) followed the treatment simulations.

Following the posttest simulation, the students all worked on a simulation representing pollen from an archaeological site.

Learning support was not embedded in this simulation.

10. The students received feedback on their performance with the computer simulations by the end of the twelfth week of class. The semester project was due December 1, 2006.

Variables and Measures

The first non-treatment practice simulation that the students worked through following the topic lectures, served as the pretest. The two treatment conditions are:

1. Treatment A - Worked example modeling with elaboration. Represented in a movie format that is embedded within a practice simulation.

2. Treatment B - Worked example modeling without elaboration. Represented in a movie format that is embedded within a practice simulation. The worked example modeling movies, both non-elaborated and elaborated, represented the expert analysis of the pollen sample found in the prior knowledge test slide. Each treatment was embedded in a different practice simulation.
<table>
<thead>
<tr>
<th>Example Narration</th>
<th>Segment 1 – Pollen Count</th>
</tr>
</thead>
</table>
| Elaborated        | Click on the microscope slide to bring it up under the microscope for scanning.  

A pollen grain or lycopodium spore image will appear in the viewing area. The viewing area image will change as you click through the scan using the scan buttons. We will start by scanning left to right all of the way across the slide. Then we scan the next row, going right to left. Note, we come down 1.5 fields at the end of each row as we scan so we don’t recount any of the grains.  

Notice also, each image has a 25 micrometer scale bar. When pollen types have similar general morphologies to other pollen types, the size may be the only factor that identifies which one you are counting. Also keep in mind that color is not a distinguishing characteristic for pollen types.  

Now to start our count, we click on the pollen image in our notebook that morphologically is similar to the image in the viewing area. For this one, this looks like a match. This next one isn’t a pollen grain. It is a lycopodium spore. We need to count these spores also. These counts will be used in calculations later in the analysis.  

Now we are coming to the end of our count. We will click tab 1 to continue now that we are finished. |
| Non-elaborated    | Click on the microscope slide to bring it up under the microscope for scanning.  

A pollen grain or lycopodium spore image will appear in the viewing area. The viewing area image will change as you click through the scan using the scan buttons.  

Now to start our count, we click on the pollen image in our notebook that morphologically is similar to the image in the viewing area. We count both pollen grains and lycopodium spores.  

Now we are coming to the end of our count. We will click tab 1 to continue now that we are finished. |

Table 3.01: Elaborated narration and non-elaborated narration examples.
A computer practice simulation that contains no embedded treatment followed all treatment simulations. This simulation was the same as the pretest simulation. This follow-up computer simulation was used as the posttest. The final simulation without embedded support had a similar structure but was in a different domain (archaeology).

Figure 3.01: Experiment flow chart.

A possible 155 point score was assessed for each of the prior knowledge, pretest, and posttests practice simulations. The point breakdown for the prior knowledge, pretest, and posttests is:

Segment 1 = 40 points (0.5 point for each 80 sections of the slide)
Segment 2 = 10 points (0.5 point for each correct common and scientific name)
Segment 3 = 5 points (0.5 point for each correct concentration)
Segment 4 = 100 points (10 points for each correct interpretation answer).

Segment 4 required the students to take the information from the three previous segments and apply it into a logical interpretation of the slide’s pollen assemblage. Thus, each question in Segment 4 was assigned a higher point score. The students were told to use all of the computer simulation answers as data in their semester projects.
The archaeology practice simulation had a possible 65 point score. The first three segments were scored the same as the prior knowledge, pretest and posttests. The interpretation quiz score was limited to one multiple-choice question. This question was “Which scenario does this pollen assemblage represent?” It was worth 10 points. This is the same overall interpretation question asked in the other three tests.

Content Validity and Reliability

The simulation instrument’s validity was established by three expert forensic palynologists. All parts of the instrument were reviewed for authentic representation of the microscopic pollen analysis process. Cronbach’s alpha scores were used to determine reliability of the instrument with this data set.

Treatments

All students were required to utilize both treatment simulations. Treatment A utilized one 3 minute 38 second narrated full process example presentation and four narrated component presentations, varying in duration (1 minute 5 seconds; 17 seconds; 39 seconds; and 1 minute 1 second). Treatment B utilized one 1 minute 55 second narrated full process example presentation and four narrated component presentations, ranging in duration (20 seconds; 8 seconds; 27 seconds; and 37 seconds). All presentations provided a modeled worked example of the same practice simulation. The palynology instructor provided the narration voice in all of the presentations. All presentations utilized the same surface story and deep structure format and were presented in accordance to the following Meichenbaum’s cognitive modeling steps:
1. A full process example was presented prior to the practice segments.

Figure 3.02: Entry page for simulations with treatment A or B. Image button loads a narrated modeled QuickTime movie of the complete simulation process.
2. The component part of the example was repeated at each of the four process steps.

Figure 3.03: “Click NOW!” button loads narrated modeled QuickTime movie of Segment 1. Once the movie is finished the user can practice the step.
Figure 3.04: “Click NOW!” button loads a narrated modeled QuickTime movie of Segment 2. Once the movie is finished the user can practice the step.
Figure 3.05: “Click NOW!” button loads a narrated modeled QuickTime movie of Segment 3. Once the movie is finished the user can practice the step.
Figure 3.06: “Click NOW!” button loads a narrated modeled QuickTime movie of Segment 4. Once the movie is finished the user can practice the step.

3. After each component presentation, the student completed a practice component of that step.

Treatment conditions:

Treatment A: The presentations modeled the worked example with the “how” and “why” information.

Treatment B: The presentations only modeled the worked example with “how” information.
All of the class periods were held in the same computer lab on the university campus. Headphones were provided for each student so computer narrations didn’t present distracting background sound.

**Instrument**

The pollen sorting practice simulation was designed in Macromedia *Flash™*. It consists of four main segments that emulate the process of pollen analysis. Prior to segment one, the user is presented with four slide choices.

![Figure 3.07: Entry page with four slide choices.](image)

Only one choice was activated during the first computer class, guaranteeing that all users work through the same prior knowledge test simulation. During the two computer class
sessions, three of the four were active at various times. The pretest simulation was active first, then the treatment, followed by the posttest during session one. The treatment simulation was active first, then the posttest, followed by the archaeology test during session two. Once the slide was chosen, the instrument took the user to the intro page of their “notebook.” This step is where the users were required to enter their project ID numbers.

Figure 3.08: Page where user enters Project Identification number.

Once the number is entered, Segment 1 begins.

Segment 1: Representation of using a microscope to count pollen from a microscope slide. The initial page had the user click on the slide to begin. The second
page had the user ‘click’ through the chosen slide. Each segment of the slide showed a pollen grain image, marker grain image or a blank image in the microscope viewing area. For each pollen image and marker grain image, the user clicked on the corresponding image in his or her notebook. This kept a running count on each pollen and marker type for the user. Once the users were finished with the complete slide count, they continued to Segment 2.

Figure 3.09: Initial page for Segment 1.
Figure 3.10: Second part of Segment 1. Scanning the slide and recording the pollen count in the notebook.

Segment 2: Identification of the pollen types that were counted in segment 1. The user utilized pollen identification sheets (provided by the instructor) to help them identify each pollen type with its common and scientific name. Once all were identified, the user continued on to Segment 3.
Figure 3.11: Identification of the ten pollen types in Segment 2.

Segment 3. Determination of pollen concentrations for each pollen type represented from the slide that was counted. The concentration formula included four number variables, two of which are numbers the user determined in the counting segment. The software was designed to place the user’s pollen and marker counts from Segment 1 into the appropriate portion of the equation. From the additional information provided in this segment (number of marker grain tablets, sample’s weight), the user determined their values and input these last two numbers for each pollen type into the formula. The software is designed so that once all of the variables are entered into the formula’s equation the user only needed to click on the equal sign for the concentration
number to be generated. This function is provided in this study to facilitate completion of the simulations within a designated amount of class time.

Figure 3.12: Computation of the pollen type concentrations in Segment 3.

Segment 4: Interpretation of the slide’s pollen assemblage. The identified pollen names and concentrations were displayed for the user in this segment. From this information the user inputs the answers to seven questions that equated to the interpretation of each slide’s pollen assemblage and overall knowledge of pollen interpretation. Only the prior knowledge, pretest, and posttest #1 and posttest #2 simulations had these questions listed in this segment. The questions were written to be objective in nature (Appendix B). The archaeology test simulation only recorded the
overall interpretation question (same as the final interpretation question in the other simulation tests) in this segment (Appendix C).

Figure 3.13: Interpretation quiz in Segment 4. This quiz is only added in Segment 4 of the prior knowledge, pretest, posttest, and archaeology simulations.

All of the segments were the same in the forensic science simulation tests as well as the final archeology simulation test except for the interpretation questions. The simulations associated with the treatment presentations were open-ended interpretation input boxes. However, the non-elaborated worked example revealed the answers to these questions in the modeled simulation and the “elaborated” worked example presentation revealed and explained the answers to these questions in the modeled simulation.
The students utilized the results from the four forensic science slides as a portion of the crime scene data they needed to incorporate in their semester project.
CHAPTER IV

RESULTS

Three expert forensic palynologists reviewed the instrument and found it to be a valid representation of microscopic pollen analysis. The simulation data obtained from the first computer class period following the topic lectures were used as the pilot study. This set of data was analyzed to determine instrument reliability using a Cronbach’s alpha score. Cronbach’s alpha scores of $\geq 0.70$ were desirable. A Cronbach’s alpha was calculated for segment one – pollen count ($\alpha = 0.903$); segment two – pollen ID ($\alpha = 0.741$, based on standardized items); segment three – pollen concentration ($\alpha = 0.967$); segment four – interpretation ($\alpha = 0.769$, based on standardized items); and overall instrument ($\alpha = 0.894$, based on standardized items). Since all Cronbach’s alpha scores were $\geq 0.70$, the instrument was determined to be reliable for this study.

Prior Knowledge Test

Prior knowledge of pollen counting, identification and site interpretation was measured for each student using the data gathered from a non-treatment computer practice simulation that the students worked through prior to the topic lectures. The AB group ($n = 19$) scored higher on the pollen counting and identification simulation ($M = 29.34$) than the BA group ($n = 20$) ($M = 28.18$). This difference was not significant, $t(37) = 0.37, p>0.05$, two-tailed. Therefore, there was no significant difference found between the two treatment groups (AB and BA) on the basis of prior knowledge.

The average percentage score for the prior knowledge academic performance by the participants was 18.55. In comparison, the average percentage score for the academic performance with lecture only (pretest) was 41.52.
Mixed Model ANOVA
To determine if embedded learning support in the form of elaborated and non-elaborated worked example modeling affected academic performance in near transfer by undergraduate college students, a mixed model (one between and one within subjects design) ANOVA was used to analyze the data at $\alpha = 0.05$.

The mixed model ANOVA was conducted with the dependent variable being the simulation test score which evaluated the level of accuracy in counting, identification, concentration calculation, and interpretation of a simulated forensic pollen sample. The test scores were determined from a posttest that followed day 1 treatments, a posttest that followed day 2 treatments, and a pretest that was taken prior to treatments. The between-subjects ANOVA was conducted with the independent variable being the group ID (AB or BA).

<table>
<thead>
<tr>
<th>Factor</th>
<th></th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within-subjects</td>
<td>Pretest</td>
<td>64.36</td>
<td>25.21</td>
</tr>
<tr>
<td></td>
<td>Posttest #1 (Oct. 2)</td>
<td>92.27</td>
<td>33.92</td>
</tr>
<tr>
<td></td>
<td>Posttest #2 (Oct. 4)</td>
<td>110.24</td>
<td>25.26</td>
</tr>
<tr>
<td>Between-subjects</td>
<td>AB</td>
<td>97.76</td>
<td>30.06</td>
</tr>
<tr>
<td></td>
<td>BA</td>
<td>80.59</td>
<td>23.51</td>
</tr>
</tbody>
</table>

Table 4.02 The means and standard deviations for level of accuracy (maximum score 155).

The sphericity assumption, for the within-subjects effect, was reviewed before the ANOVA results were examined to determine if it was tenable or not. To determine this, the Mauchly’s Test of Sphericity was examined. The Mauchly’s Test indicated a
statistically non-significant difference, $W = 0.92, p = 0.22$. Preliminary analyses also indicated that the sphericity assumption is tenable, given a Huynh-Feldt value of 1.00.

**Within-subjects and Between-subjects Interaction**

With the sphericity assumption met, a univariate mixed method test was run using SPSS. The univariate test indicated a non-significant interaction between the within-subjects factor and the between-subjects factor, sphericity assumed, $F(2,74) = 0.08, p = 0.93$.

**Between-subjects Factor**

The results for the between-subjects factor main effect indicated a significant group ID (AB, BA) effect, $F(1,37) = 6.11, p =0$. This indicates that there is a significantly better academic performance in Group AB compared Group BA in all three tests (pretest, posttest #1, posttest #2). The effect size for the analysis is large, $\eta^2_p = 0.14$. In other words, 14% of the total variability of the level of accuracy can be explained by the group ID assignment, regardless of treatment presence.
Figure 4.01: Profile plot of the mixed model ANOVA marginal means.

**Within-subjects Factor**

The results for the within-subjects factor indicated a significant worked example treatment effect, $F(2, 74) = 49.39, p < 0.01$. The effect size for the analysis is large, $\eta^2_p = 0.57$. In other words, 57% of the total variability of the level of accuracy can be explained by repeated use of worked example modeling.

To determine where the significant differences were among the worked example treatment means, the pairwise Tukey’s HSD Test was conducted on the mean differences. Table 4.03 shows that this analysis yielded three statistically significant pairwise
differences. The first significant pairwise difference was between Posttest #1 group and Pretest group. The Posttest #1 group yielded academic performance scores statistically significantly higher than the Pretest group’s scores. The second significant pairwise difference was between Posttest #2 group and Pretest group. The Posttest #2 group yielded academic performance scores statistically significantly higher than the Pretest group’s scores. The third significant pairwise difference was between Posttest #2 group and Posttest #1 group. The Posttest #2 group yielded academic performance scores statistically significantly higher than the Posttest #1 group’s scores.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Mean Difference</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posttest #1 vs. Pretest</td>
<td>27.899*</td>
<td>0.94</td>
</tr>
<tr>
<td>Posttest #2 vs. Pretest</td>
<td>45.918*</td>
<td>1.82</td>
</tr>
<tr>
<td>Posttest #2 vs. Posttest #1</td>
<td>18.020*</td>
<td>0.61</td>
</tr>
</tbody>
</table>

*Tukey’s HSD statistically significant at $p < .05$.

Table 4.03: The mean difference and effect size for each pairwise comparison.

For these results, a standardized mean difference measure was used for describing the pairwise differences between the groups even further by calculating the Cohen’s $d$ effect size between each comparison. This measure expresses the mean difference between the groups in standard deviation units. As seen in Table 4.03, the statistically significant comparison (Posttest #1 group and Pretest group) yielded a value ($d = 0.94$) that Cohen (1988) would classify as a large effect size. These two group means are a little over 9/10 of a standard deviation apart. The statistically significant comparison (Posttest #2 group and Pretest group) yielded a value ($d = 1.82$) that Cohen (1988) would classify as a large effect size. These two group means are “approaching” two standard deviations.
apart. The third statistically significant comparison (Posttest #2 group and Posttest #1 group) yielded a value \( d = 0.61 \) that Cohen (1988) would classify as a medium - large effect size. These two group means are a little over 6/10 of a standard deviation apart.

**Isomorph Test**

Academic performance in the archaeology simulation was measured for each student using the data gathered from a non-treatment archaeological pollen sample simulation. To determine if embedded learning support affected academic performance in near transfer within an isomorphic context provided from a different domain, an independent \( t \) test was used to analyze the data between the two treatment groups (AB, BA). The AB group \( (n = 19) \) scored higher on the pollen simulation \( (M = 57.66) \) than the BA group \( (n = 20) \) \( (M = 53.78) \). This difference was not significant, \( t(37) = 1.95, p > 0.05 \), two-tailed. Therefore, there was no significant difference detected between the two treatment groups (AB and BA) on the basis of near transfer within an isomorphic context within a different domain.

The final forensic near transfer scores were re-calculated to reflect the performance with only the one overall pollen assemblage interpretation question that was answered in the archaeology test (Appendix C). An independent \( t \) test was used to analyze the data between the AB and BA treatment groups. The AB group again scored higher on the pollen simulation \( (M = 54.84) \) than the BA group \( (M = 53.13) \). This difference was, however, not significant, \( t(37) = 0.78, p > 0.05 \), two-tailed. Therefore, there was no significant difference between the two treatment groups (AB and BA) on the basis of near transfer performance that only included an overall interpretation of the pollen assemblage.
Comparison between the average percentage score for the forensic near transfer performance and for the archaeology near transfer performance, suggests a slightly better transfer success with the archaeology problem. The average percentage score for the academic performance in participants’ archaeology near transfer score was 85.72. In comparison, the average percentage score for the academic performance in participants’ final forensic near transfer score was 83.06.
<table>
<thead>
<tr>
<th>Transfer</th>
<th>$n$</th>
<th>$M$</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>forensic</td>
<td>39</td>
<td>53.99</td>
<td>83.06</td>
</tr>
<tr>
<td>archaeology</td>
<td>39</td>
<td>55.72</td>
<td>85.72</td>
</tr>
</tbody>
</table>

Table 4.04: The means and percentages of accuracy (maximum score 65).
CHAPTER V

DISCUSSION

Each of the research questions and hypotheses presented in this study will be addressed in this chapter. For convenience of reference they are listed below.

Research Question 1:

Does embedded learning support in the form of worked example modeling affect the academic performance of the students?

Research Question 2:

Is there a significant difference between embedded modeled worked examples without elaboration and embedded worked examples with elaboration?

Research Question 3:

Do multiple practice simulations with embedded learning support affect academic performance within practice simulations that have the same logic structure but are set in different domains (isomorphs)?

Hypothesis 1:

Procedural practice simulations with embedded learning support in the form of worked example modeling will provide a significant increase on the academic performance of the students.

Hypothesis 2:

Procedural practice simulations with embedded elaborated worked example modeling compared to non-elaborated worked example modeling will provide a greater significant cognitive transfer with novice learners due to reduction in cognitive load, but may produce a negative affect with more advanced
learners due to lack of attention from a misconception of looking “too easy.”

The advanced learner loses focus and motivation which limits the amount of ability the learner will allocate to the task, causing an under utilization of working memory (Brooks & Shell, 2006).

**Hypothesis 3:**

Multiple procedural practice simulations with embedded learning support can affect transfer between isomorphs, where logic is the same but the physical context is different (different domains), but may produce a ceiling affect with more advanced learners.

**Prior Knowledge Test**

The results of the prior knowledge simulation test indicate that both groups of students were similar in prior knowledge and can be classified as novice learners in the topic of forensic palynology analysis. Previous research has shown that novice learners have difficulties with selecting and organizing relevant material and often form misconceptions (Rieber, 1990, Lowe, 2003). The learner must be able to select relevant material, organize it into a meaningful representation so it will integrate into their existing knowledge. (Mayer, 2001). In addition, as was discussed earlier, Rieber (1999a & b) warns that novice learners often do not possess the ability to correctly interpret the learning activity. Some of the errors made in the prior knowledge and to a lesser extent in the pretest can be credited to a lack of knowledge with the activity as well as with the topic. Even though written instructions were included at each step in the simulation presented in the original class session, the students were noticeably unsure about how to proceed through the simulation activity. After obtaining information from the topic
lectures and watching the instructor click through the sequence of steps in the activity, there still was a level of uncertainty on how to proceed through the process of the activity during the pretest. What the study results do allude to is that the worked example modeling successfully played the role of the expert coach, a strategy suggested by Rieber to overcome this problem of indecisiveness with novice learners.

**Research Question 1**

This research found a significant increase in academic performance with the inclusion of embedded learning support in the form of worked example modeling within a computer simulation. After exposure to one worked example, regardless of the presence of elaboration or not, these findings tentatively verify Ahn, Brewer and Mooney’s (1992) conclusion that, when using an explanation-based leaning approach on concept formation, schema can be acquired from a single example in a knowledge-rich domain. Also supported was Renkl, et al.’s (1998) conclusion that it is not necessary to include multiple examples for near transfer goals. However, results of this research do indicate a positive linear trend with exposure to multiple worked example modeling (Figure 4.01). The students’ exposure to two worked example models may explain the similar performance success in the archaeology posttest (85.72% accuracy) to the final forensic transfer posttest (83.06% accuracy).

The inclusion of embedded worked example models indicates a linear trend. One may suggest that this skill development is due to practice. To a certain extent, one would certainly assign a relationship of the positive increase in academic performance to the multiple attempts the students did of the “pretest/posttest” slide. However, there was no immediate or delayed feedback given to the students on the numerous attempts. Thus, we
return to the fact that previous research (Cooper & Sweller, 1987; Sweller & Cooper, 1985) has found traditional practice-based problem solving strategies to be lacking in success. It would tentatively suggest that the practice success was only an effective method of acquiring cognitive skills for novices, once the embedded worked example modeling was present. The embedded worked example modeling elements, in this study, have shown significant research effects for better transfer ($\eta_p^2 = 0.57$, $\eta_p^2 = 0.45$, $\eta_p^2 = 0.36$) suggesting reduction of cognitive load for the novice students. This is not surprising in that the instructional design of this research’s simulation activity incorporates Mayer and Moreno’s nine ways of reducing cognitive overload in multimedia learning.

When considering the effectiveness of the embedded worked example modeling in each step, some research studies (Clarke, Ayres, & Sweller, 2005; Kester, Kirschner, & van Merriënboer, 2004a, 2004b; and Pollock, Chandler, & Sweller, 2002) argue that a part-whole approach is effective in reducing intrinsic load in learning complex tasks. However, this study utilizing Meichenbaum’s steps for cognitive modeling has shown that providing a complete presentation of the complexity of the process at the beginning followed with short segment clips at each step of the process, has a significant effect on performance. These results connect this present research’s significance of the worked example modeling to the notion that a whole-part approach is a successful method through which to reduce intrinsic load in complex learning tasks. Previous literature (Dufresne, Gerace, Thibodeau-hardiman, & Mestre, 1992; van Merriënboer, Kester, & Paas, 2006) has suggested that one way to present a whole-part approach is “…to constrain learners’ performance, either through forcing them to behave as an expert
would do by requiring them to successfully complete a particular problem-solving phase before entering a next phase or through the use of particular tasks formats such as worked examples and completion tasks’’ (van Merriënboer et al., 2006, p. 348). The Meichenbaum steps utilize this enforcement of expert behavior in requiring the completion of each task before entering the next task or phase. This research study found that this whole-part approach was effective in academic performance of novice learners and suggests that presentation of the complete process with individual follow up segments at each step of the process does reduce intrinsic load for these learners as suggested by Meichenbaum (1977).

This study also suggests that the delayed use of feedback was a factor contributing to the success of transfer. This delayed use of feedback is supported by van Merriënboer, et al. (2006) as a method to induce germane cognitive load. A study by Robins and Mayer (1993) also “…found superior transfer test performance for learners who received sets of worked examples together with infrequent feedback” (van Merriënboer, et. al., 2006, p. 349).

The results from this study’s repeated measure performance effect size ($\eta^2_p = 0.57$) provides additional support for Lee’s (1999) findings that the effectiveness of using computer simulation practice in science education has an average effect size of 0.54.

Research Question 2

It was hypothesized that procedural practice simulations with embedded elaborated worked example modeling compared to non-elaborated worked example modeling would provide a greater significant cognitive transfer with novice learners due to reduction in cognitive load. However, no significant difference was found in utilizing
elaborated vs. non-elaborated worked example modeling. This study’s practice simulation was formulated to represent a process developed in a well-structured scientific domain. Thus this finding is attributed to the fact that the goal state is well defined and that there is only one path that will lead to the correct (acceptable) solution. This then does not support the rationale by van Gog et.al.’s (2004) for utilizing the “expert” why and how in worked examples. However, their suggestion that the addition of the “expert” why would foster better understanding in less structured domains has not been discounted and further research is suggested. van Merriënboer et al. (2006), when discussing methods to induce germane cognitive load, refers to a study by Renkl (2002) that “…indicated using guidance, in the form of a minimalist description of the probabilistic rule that was used in the worked example provided, had beneficial effects on learning” (van Merriënboer et al., 2006, pp. 348-349). Thus the inclusion of non-elaborated worked example modeling may actually be more beneficial in this regard.

Research Question 3

The present research has demonstrated a significant linear trend of exposure to multiple worked example modeling. After exposure to two worked example models, the students performed as well on the archaeology transfer posttest (85.72%) as the final forensic near transfer posttest (83.06%). Renkl et al.’s (1998) concluded that it is necessary to include multiple examples when far transfer is the goal, but this may be also necessary in transfer between isomorphs.

In reviewing this study, the concept of analyzing pollen samples from a human occupation site to determine human activity within the context of two different domains can be argued that the transfer of knowledge is the same and only represents near transfer
in both. However, Perkins (1992) presents a discussion of transfer with isomorphs that pertains to this argument. He states, “[I]t is not clear whether one should consider study of problem isomorphs near or far transfer, because isomorphs are near identical structurally but very different in external trappings. In any case, subjects usually do not recognize the connection between one isomorph and the other and hence do not carry over strategies they have acquired while working with one to the other. However, if the relationship is pointed out, then subjects can do so fruitfully (Simon & Hayes, 1977)” (Perkins, 1992, p. 4). So, if one views the use of palynology techniques in forensic science and archaeology as isomorphs, with the same logical structure in different physical terms (the forensic structure presented entirely with the present day time frame and a murder investigation context while the archaeology structure is presented with a prehistoric time frame in a hunter-gatherer habitation context), the success lies in the order of practice with the archaeology simulation following the forensic simulation. This allowed the students to successfully carry over the process strategies. The argument for domain transfer success is a necessary argument when validation of scientific techniques, developed for analysis in one domain, is to be accepted as a valid technique in other domains. In this study, pollen analysis was taught as an analytical tool in a science field that has incorporated multiple hard science techniques to support conclusions in a court of law. Bryant, Jones, and Mildenhall (1990) define forensic palynology as “…the science of applying modern and fossil pollen and spores (palynomorphs) to help solve legal problems” (p. 193). The utilization of forensic palynology in solving legal problems was first documented in 1959 (Bryant & Mildenhall, 2006).
Literature references to archaeological palynology, however, can be traced back to the 1920s. Archaeological palynology has been utilized in the soft science field of archaeology as a method of interpreting the health, diet, and activity patterns of ancient populations.

“Instructional methods that explicitly aim at transfer of learning must carefully balance both complementary dimensions, and facilitate the interpretive aspects of knowing for those aspects of a complex task that are different from problem to problem situation as well as facilitate the applicative aspects of knowing for those aspects of a complex task that are highly similar from situation to situation (van Merriënboer, 1997)” (van Merriënboer et al., 2006, p. 346). The results from this study suggest that, with the adaptation of practice simulation utilizing the same mechanical procedure in two different physical domain contexts, but containing similar interpretation logic, the practice simulation incorporates an instructional method that contains aspects of transfer of knowledge in science as well as other non-science domains through the utilization of the worked example modeling.
CHAPTER VI

CONCLUSIONS

This research study focused on embedded worked example modeling within practice simulations as an instructional design model for enhancing knowledge transfer for promotion of schema acquisition. The findings suggest that embedded worked example modeling within practice simulations can be an effective method for transfer of learning with novice learners. In addition, the findings suggest that this is a method that can be utilized as part of course curriculum for enhanced instruction on complex tasks. There are however, still some questions to be answered to determine all of the intricacies of this model.

There were limitations to the final conclusions of this research. These limitations include:

1. The sample size was limited to the enrollment number for the Introduction to Forensic Science course. This sampling procedure limits the generalization of the results.

2. The use of a convenience sample classifies this as a quasi-experiment.

3. The class enrollment was 50. To increase power a repeated measures counter balance design will be used.

4. By using a mixed model for analysis with the data, only repeated measure subject data that were complete for all three tests (pretest, posttest#1, posttest#2) were used in the analysis by default of the
SPSS program. Thus, only 39 out of the 50 subject sets were utilized in all results.

5. Due to class time limitation for practice sessions, only one modeled worked example per treatment condition was utilized.

This research points to these areas for future research. First, more research is needed to determine if the linear trend of worked-example modeling is continuous or if it plateaus out possibly as learners move out of the novice category. This concept is valuable as one designs practice simulations that can be utilized with learners at varying levels of expertise. The number of different examples dictates the time and effort the production of a practice simulation will require. The decision to include an elaborated worked-example model as embedded learning support within a practice simulation, needs to be weighed against the time and effort factors since both elaborated as well as non-elaborated versions showed significant gains in academic performance by novice learners. The practical aspects of the real classroom environment primarily imposed this study’s time constraints. Classroom constraints need to be addressed and kept in mind while still in the instructional design phase of a simulation project. Once utilization includes out-of-class time, certain factors of time restraints become less of an issue, while other confounding variable issues now dominate the design concerns.

Follow-up research also is needed to address the individual usage of each segment movie clip. If certain steps or segments within a process prove to be more difficult for most novice learners than other segments, then these segments may need the elaboration while the others do not.
Additional research also should be done on how effective the transfer of what was presented in the simulation practice is in its real life counterpart’s process. That is, how well would students perform using microscopes and pollen slides in a real laboratory both with and without prior simulation experience? Renkl et al.’s (1998) concluded that it is necessary to include multiple examples when far transfer is the goal. Thus, this additional research should contain elements to help determine numbers of practice simulations with worked example modeling that are effective in far transfer to a real laboratory setting.
REFERENCES


Tennyson, R. D., Wooley, F. R., & Merrill, M. D. (1972). Exemplar and nonexemplar variables which produce correct concept classification behavior and specified classification errors. *Journal of Educational Psychology*, 63, 144-152.


Appendix A

IRB APPROVAL DOCUMENT

August 15, 2006

Debra Meier
Dr. David Brooks
2020 Smith Street
Lincoln NE 68502

IRB# 2006-08-517 EX

TITLE OF PROJECT: Analyzing the impact of elaborated modeling in a computer simulation for promotion of schema acquisition

Dear Debra:

This letter is to officially notify you of the approval of your project by the Institutional Review Board (IRB) for the Protection of Human Subjects. This project has been approved by the Unit Review Committee from your college and sent to the IRB. It is the Board’s opinion that you have provided adequate safeguards for the rights and welfare of the participants in this study. Your proposal seems to be in compliance with this institution’s Federal Wide Assurance 00002258 and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46) and has been classified as exempt.

Date of EX Review: 08/04/06

You are authorized to implement this study as of the Date of Final Approval: 08/14/06. This approval is Valid Until: 08/13/07.

This project should be conducted in full accordance with all applicable sections of the IRB Guidelines and you should notify the IRB immediately of any proposed changes that may affect the exempt status of your research project. You should report any unanticipated problems involving risks to the participants or others to the Board. For projects which continue beyond one year from the starting date, the IRB will request continuing review and update of the research project. Your study will be due for continuing review as indicated above. The investigator must also advise the Board when this study is finished or discontinued by completing the enclosed Protocol Final Report form and returning it to the Institutional Review Board.

If you have any questions, please contact Shirley Horstman, IRB Administrator, at 472-9417 or email at shorstman1@unl.edu.

Sincerely,

[Signature]

Dan R. Hoyt, Chair
for the IRB

[Signature]

Shirley Horstman
IRB Administrator

cc: Unit Review Committee
APPENDIX B

INTERPRETATION QUESTIONS

Interpretation Points (Questions)

1. Is this pollen assemblage dominated by wind or insect pollinated types?
   ANSWER: wind (insect) (10 pt.)

2. Name four pollen types that would be typical in a normal pollen rain in Nebraska?
   ___________________, ________________, ________________, ________________
   ANSWER: ___________________ (40 pt.)

3. What is the main characteristic of typical Nebraska pollen rain?
   ANSWER: wind pollinated (1 pt.)

4. If any of the normal pollen rain types in this sample, have an elevated concentration over its typical pollen rain concentration, this may suggest ________________.
   ANSWER: human influence (10 pt.)

6. If a sample is dominated by natural pollen rain types for the immediate area surrounding the crime scene, how can this sample be used in reference to the other samples from the crime scene?
   ANSWER: control (1 pt.)

7. If a sample is dominated by insect pollinated types, one of the reasons may be that the sample represents ________________.
   ANSWER: diet, decorative flowers in pots, or cultivated plants (10 pt.)

8. Which scenario does this pollen assemblage represent?
   a. person’s last meal
   b. typical Nebraska environmental pollen
   c. typical New Mexico environmental pollen
   d. typical California environmental pollen
   e. mixture of Nebraska and New Mexico pollen
   f. mixture of Nebraska and California pollen
   g. mixture of New Mexico and California pollen
   ANSWER: depends on the slide (10 pt.)

TOTAL = 100 pts.
Interpretation Points (Question)
1. Which scenario does this pollen assemblage represent?
   a. person’s meal
   b. typical Nebraska environmental pollen
   c. typical New Mexico environmental pollen
   d. typical California environmental pollen
   e. mixture of Nebraska and New Mexico pollen
   f. mixture of Nebraska and California pollen
   g. mixture of New Mexico and California pollen

ANSWER: a (10 pt.)

TOTAL = 10 pts.