Perceived Role of Multimedia Instructional Materials on Multicriteria Technology and Engineering Decisions

Victor Mbarika  
Assistant Professor  
Department of Information Systems and Decision Sciences  
Louisiana State University  
Baton Rouge, LA 70803  
vmbarika@aol.com

Chetan S. Sankar  
Thomas Walter Professor  
Department of Management  
Auburn University, AL 36849  
sankar@business.auburn.edu

P.K. Raju  
Thomas Walter Professor  
Department of Mechanical Engineering  
Auburn University, AL 36849  
pkraju@eng.auburn.edu

Keywords: Multimedia, Instructional Materials, Decision Making, Business, and Engineering.

Accepted for Publication in the  
Perceived Role of Multimedia Instructional Materials on Multicriteria Technology and Engineering Decisions

ABSTRACT

Studies have shown that it is difficult for people to deal with multicriteria decision-making situations. Information technology tools such as Decision Support Systems and Expert Systems have been developed in order to help them in such situations. Another tool that has been identified as helping managers understand complex engineering decision-making situations is multimedia instructional materials. This research investigates the perceptions of business versus engineering students on improvement of their higher-level cognitive skills when they participated in a multimedia based case study that used an expert system to model a complex engineering and technical problem.

Two groups of students, business and engineering, participated in an experiment where they analyzed the case study and made their recommendations. Two questionnaires measured their perceptions on the improvements achieved on different constructs. A structural equations model was developed in order to test the research hypotheses with business students being the experimental group and the engineering students as a control group. The major findings are: no significant relationship between student major and higher order cognitive skills improvement, business students perceived more higher-order skills improvement compared to engineering students, both groups perceived an improvement in learning-driven factor, and business students valued learning-driven factors compared to engineering students. These results show that multimedia instructional materials were perceived to be very useful in making multicriteria engineering and technical decisions.
Introduction

Employers and top executives in companies want their managers and workers to be above average problem solvers, decision makers, and team players (Bargeron et al., 2002). They are enthusiastic when new recruits exhibit higher-order cognitive skills that will enable them to handle the complex and interrelated issues that affect the company’s performance and sustainability in the 21st century. (Rieley and Crossley, 2000) The need for higher-order cognitive skills has been perceived to be much more important when people deal with multicriteria decision-making situations. For example the United States National Aeronautics and Space Administration (NASA) is working to boost higher-order cognitive skills of flight crews. This is due to the discovery that decision errors are second only to procedural errors in being the direct cause of flight-crew involved accidents, patterns of differences between good and bad crews, and pilots' perception of risk (Dornheim, 2000). These difficulties are also prevalent in other industries. Studies have shown that it is difficult for people to deal with multicriteria decision-making situations. Researchers state that to prepare students to be successful as they go on to enter the work force it is critical to provide them an education that encompasses higher-order cognitive skills such as reasoning, problem identification, criteria specification, integrating, interrelating and problem solving (King, 2000; Guzdial and Soloway, 2002).

Information technology tools such as Decision Support Systems and Expert Systems have been developed in order to improve the higher-order cognitive skills of students and employees (Cole, 2000; Hassan, 2000; Tan and Thoen, 2000). Another tool that has been identified as helping managers deal with complex engineering decision-making situations is multimedia instructional materials (Raju and Sankar, 1999; Mbarika, et al., 2001).
Multimedia instructional materials are those materials used for instruction that include one or more media such as graphics, video, animation, images, and sound in addition to textual information (Fetterman, 1997, Beckman, 1996). The impact of multimedia instructional materials on a person’s higher order cognitive skills improvement is not well established (Dillon and Gabbard, 1999). Therefore, we formulated the following research question: Given complex engineering and technological decisions that business students have to deal with in their career, does multimedia instructional material enhance their higher-level cognitive skills?

This paper answers this question by reporting the results of an experiment conducted with business and engineering students in order to examine their perceptions of how the multimedia case studies improved their higher-level cognitive skills. A case study that incorporates a real-world engineering and technical problem was chosen as the basis of the study. This case study was supported by a multimedia CD-ROM that included videos and photographs from the plant that brought the problem alive to the audience. In addition, an expert system was incorporated in the case study that modeled the multicriteria decision situation and provided an opportunity for performing sensitivity analysis on the recommendations. A research model was developed that led to the identification of the constructs and factors used in this study. Two groups of students, business and engineering, participated in an experiment where they analyzed the case study and made their recommendations. Two questionnaires measured their perceptions on the improvements achieved. A structural equations model was developed in order to test the research hypothesis with business students being the experimental group and the engineering students as a control group. The results of the experiment reveal significant findings on the ability of multimedia instructional materials to perceived improvement of higher-level cognitive skills. This leads to a series of recommendations and future research topics.
Researchers disagree over what impact multimedia has on students’ higher order cognitive skills improvement. Some of the positive findings are from Nielsen, Collier, Barrett, Jonassen, Delany and Gilbert, and Oliver. Nielsen reports that multimedia enables non-linear access to vast amounts of information (Nielsen 1995). Other researchers show that with multimedia, users can explore information in-depth on demand and interact with instructional material on a self-paced mode (Collier, 1987; Barrett, 1988). Others state that multimedia is attention-capturing or engaging to use and represents a natural form of representation with respect to the workings of the human mind (Jonassen, 1989; Delany and Gilbert, 1991). Oliver and Omari (1999) carried out a qualitative research study to investigate the learning behaviors of classroom-based students in a World Wide Web (WWW) learning environment. The study suggested that while print instructional materials provided a sound means to guide and direct students’ use of the WWW learning materials, the actual WWW materials were more suited to supporting interactive learning activities rather than conveying content and information. Mbarika et al. (2001) found that use of multimedia does improve students’ perceived higher Order Cognitive Skills when learning engineering issues.

Negative findings are reported by Dillon, Gabbard, Orr, Poindexter, Allen, VarHagen, Zumbo, Clark, and Landauer. Dillon and Gabbard (1999) reviewed the findings of 35 experimental studies of multimedia use in educational tasks that emphasized quantitative and empirical methods to assess learning outcomes. The findings from this research indicated that the benefits of multimedia in education were limited to learning tasks reliant on repeated manipulation and searching of information. Individual differences in the response of learners to
this technology seem to be significant. They report that there is not convincing evidence for increased learning in multimedia environments. Orr, Poindexter and Allen (1998) concluded that using multimedia-based information technology in computer-related courses will not positively impact learning. VarHagen and Zumbo (1990), in a study of computer-assisted instruction, found positive student perceptions but no impact on student higher order cognitive skills improvement. Clark (1985) had suggested that positive student perceptions and performance in such situations may result as much from the novelty of the information technology environment as from the impact of the technology on the teaching and learning process. Landauer (1995) reported that despite numerous published reports on the topic of multimedia use, only nine studies of human performance with this technology met minimally acceptable scientific criteria.

**Research Model**

Given the conflicting results from the literature review, the researchers decided to use multimedia instructional technologies to augment a written case study that brought complex technical and engineering problems to the classroom. We tested this case study with engineering and business students to see if multimedia case studies could improve students’ higher order cognitive skills. The research questions were:

- Is there a direct relationship between the student major (Business versus Engineering) and higher order cognitive skills improvement?
- Is there an indirect relationship between the student major (Business versus Engineering) and higher order cognitive skills improvement with any intervening variables?

The second question was created since earlier research (Goodhue and Thompson, 1995; Mbarika et al., 2001) showed that intervening variables such as learning-driven and content-
driven factors might explain why perceived higher-level cognitive skills improved. Therefore, the intervening variables from past literature (Goodhue and Thompson, 1995; Mbarika et al., 2001) were included in the research model. The corresponding research hypotheses as shown in Figure 1 are:

**H1:** There is a direct perceived relationship between student major and higher-order cognitive skills improvement when using multimedia instructional materials.

**H2:** There is an indirect perceived relationship between student major and higher-order cognitive skills improvement when using multimedia instructional materials, with the intervening variables being Learning-Driven and Content-Driven factors.

The student-major construct in this model was manipulated by a two-dimensional variable: Business versus Engineering students. Perceived higher order cognitive skills improvement was measured by a set of items that were validated in earlier research studies. The constructs and items corresponding to Learning-Driven and Content-Driven factors were derived from past literature. Each of these factors is defined next.
Figure 1: Direct and indirect relationship between student major and perceived higher order cognitive skills improvement (with Learning-Driven and Content-Driven factors as the intervening variable for the indirect impact).

Student-Major

Student-Major indicated whether the student was a business student or an engineering student. In this study student-major was indicated by a dummy variable (0 indicates an engineering student; 1 indicates a business student).

Learning-Driven Factor

Learning-Driven Factor is composed of constructs that show the intrinsic value of the instructional materials to the end-user. For example, the constructs of learning interest, challenging, self-reported learning, and learned from others measure the end-user’s perceived intrinsic achievements due to the experiment. Each construct was measured using multiple items.
as defined in the Hingorani et al., (1998), and Goodhue and Thompson (1995) studies. The constructs are defined below.

- **Learning interest** was used to evaluate how much the case study drew students’ interest during and after the experimental sessions.

- **Challenging** was used to evaluate whether the case study successfully brought real life problems to the classroom, was helpful in learning difficult management and engineering topics, and was helpful in transferring theory to practice.

- **Self-reported learning** was used to evaluate whether the case study improved students’ understanding of basic concepts and whether the students learned to identify central management and technical issues.

- **Learned from others** was used to evaluate whether the students learned from one another by valuing other students’ point of view or by interrelating important topics and ideas.

**Content-Driven Factor**

Content-Driven Factor is composed of constructs that measure the extrinsic value provided to the end-user by the use of multimedia instructional materials. It includes the constructs of quality, locatability, ease of use, and timeliness. These constructs were adopted from the Goodhue and Thompson (1995) study.

The constructs are defined below.

- **Quality** was used to determine whether the data used was current enough to meet the students’ need to evaluate the case study. Quality also determined whether it was the
right data (maintaining the necessary fields or elements of data) and had the right level of detail.

- **Locatability** was used to refer to the ease of determining what data was available, where the data was available, and the ease of determining what a data element meant, or what was excluded or included in calculating it.

- **Ease of use** was used to refer to the ease of doing the assigned task using the system hardware and software for submitting, accessing, and analyzing data, and getting the kind of quality computer-related training necessary to complete the assigned task.

- **Timeliness** was used to determine whether the students’ tasks were completed on time.

**Higher-Order Cognitive Skills**

Higher-Order Cognitive skills relates to the perception that an individual has acquired an adequate portfolio of skills to make a decision within a specified period of time. It implies an improved ability to identify, integrate, evaluate, and interrelate concepts within the case study, and hence make the appropriate decision in a given problem-solving situation. This construct was derived from Hingorani et al. (1998) study and includes the following items: Identify, integrate, evaluate, confident, interrelate, connect, decision-making, and problem-solving.

Higher-Order Cognitive skills isn't a new concept. Described as early as the 1950s, it entered the general education literature as a way to enhance learning. This concept has been re-emphasized in the last decade, especially in nursing and medical education. Higher-Order Cognitive skills is purposeful, outcome-directed thinking that's based on a body of scientific knowledge derived from research and other sources of evidence. Its approach is broader than merely seeking a single solution to a problem. It involves identifying options or alternatives,
such as nursing interventions, and then selecting one that's best for meeting the desired outcome. In other words, the outcome directs and gives meaning to the task. Anyone can learn critical thinking, but it's a long-term development process that must be practiced, nurtured, and reinforced over time. For example, in the field of Nursing, the expert critical thinker uses the following six essential cognitive skills (Ignatavicius, 2001).

1. Interpretation involves clarifying meaning, such as determining the significance of laboratory values, vital signs, and physical assessment data. It also includes understanding the meaning of a patient's behavior or statements.

2. Analysis is determining the patient's problems based on assessment data. At times, the actual problem can't be validated initially, but several possibilities, or arguments can be identified.

3. Evaluation is identifying expected patient outcomes and assessing whether or not they're met. If not met, the nurse ascertains why.

4. Inference is about drawing conclusions. For example, the nurse determines when a patient's health status improves or declines through careful monitoring.

5. Explanation is the ability to justify actions. The nurse implements interventions based on research or other sources of evidence.

6. Self-regulation is the process of examining one's practice and correcting or improving it if necessary.

Table 1 lists the items that were used to measure the constructs and factors used in the research model.
Table 1: Items used to measure constructs under learning-driven and content-driven factors

<table>
<thead>
<tr>
<th>Construct</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Constructs Under Learning-Driven Factor</strong></td>
</tr>
<tr>
<td><strong>Self Reported Learning</strong> (3 items)</td>
<td>Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues. (Hingorani et al, 1998)</td>
</tr>
<tr>
<td><strong>Learning Interest</strong> (3 items)</td>
<td>Discussed technical and managerial issues outside of class, did additional reading on technical and managerial issues, did some thinking for myself about technical and managerial issues. (Hingorani et al, 1998)</td>
</tr>
<tr>
<td><strong>Learned from Others</strong> (2 items)</td>
<td>Learned to value other students’ point of view, learned to inter-relate important topics and ideas. (Hingorani et al, 1998)</td>
</tr>
<tr>
<td><strong>Challenging</strong> (4 items)</td>
<td>Successful at bringing real life problems to the classroom, challenging, helpful in learning difficult topics, helpful in transferring theory to practice. (Hingorani et al, 1998)</td>
</tr>
<tr>
<td></td>
<td><strong>Constructs Under Content-Driven Factor</strong></td>
</tr>
<tr>
<td><strong>Timeliness</strong> (2 items)</td>
<td>Task completed on time, case study reports delivered on time. (Goodhue and Thompson, 1995)</td>
</tr>
<tr>
<td><strong>Ease of use</strong> (3 items)</td>
<td>Easy to learn, easy to use, had enough training to use the case study. (Goodhue and Thompson, 1995)</td>
</tr>
<tr>
<td><strong>Quality</strong> (6 items)</td>
<td>Current, up to date, needed data, useful, appropriate level of detail, sufficiently detailed. (Goodhue and Thompson, 1995)</td>
</tr>
<tr>
<td><strong>Locatability</strong> (4 items)</td>
<td>Easy to find, easy to locate, obvious, exact definitions of terms were available. (Goodhue and Thompson, 1995)</td>
</tr>
</tbody>
</table>

**Research Methodology**

The hypotheses were tested by administrating a field experiment in a classroom at a major southeastern university. This section describes the instructional materials, the experimental design, the subjects, the instrument, and the analysis procedures used in this study.
Instructional Materials

Overview of a Case study to Bring Multicriteria Engineering and Technical Decision to the Classroom

A case study, CRIST Power Plant, was developed by working with Gulf Power Company in order to bring real-world engineering and technical issues to classrooms. (Sankar, Raju, and Kler, 1997, Sankar and Raju, 2000). The researchers discussed with the plant manager the maintenance and planning schedules of a turbine-generator unit in the plant during January to August of 1997. Then, they visited the plant and observed the actual implementation of the decision during January to March 1998. A CD-ROM was created in order to show the problem to students (Sankar and Raju, 2000). The problem addressed in this case study is provided below.

Joe, the plant manager had to choose an alternative so that it could be implemented during next year’s planned maintenance of turbine generator unit #4. The unit to be maintained was put into operation during 1959 and had been vibrating excessively and giving problems in the operation of its generator rotor, stator, and retaining rings. The management team had created five alternatives that could be implemented. They generated a table that showed the alternatives and costs involved with that. Each alternative offered a different combination of options as well as varying costs (Table 2).

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Use of the 1960's stator bars</th>
<th>Install new stator bars</th>
<th>Block and repair rotor</th>
<th>Buy spare rotor with retaining rings</th>
<th>Replacing retaining rings</th>
<th>New generator set</th>
<th>Labor costs</th>
<th>Overall costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$550,000</td>
<td>---</td>
<td>$150,000</td>
<td>---</td>
<td>$300,000</td>
<td>---</td>
<td>$200,000</td>
<td>$1,210,000</td>
</tr>
<tr>
<td>2</td>
<td>---</td>
<td>$850,000</td>
<td>$150,000</td>
<td>---</td>
<td>$300,000</td>
<td>---</td>
<td>$110,000</td>
<td>$1,410,000</td>
</tr>
</tbody>
</table>
Mark from Information Services had worked with Jimmy, the Superintendent of Engineering and Administration, and prioritized the alternatives using a Decision Support System called *Expert Choice*. This software is based on the theory of Analytic Hierarchy Process (Saaty, 1990). This software assists a decision maker in solving complex problems that involve many criteria and several courses of action. It provides the tools to construct decision frameworks from both routine and non-routine problems and to utilize these decision frameworks in ways that include your own value judgments. Using this software, Mark identified the goals, alternatives, criteria and sub-criteria involved in making the decision (Figure 2). After developing the model, the next step is to compare the criteria of cost and risk, then compare the sub-criteria against each other and finally compare the alternatives under each sub-criterion.

Then Mark used the model to evaluate the relative worth of each alternative. The Expert Choice model synthesizes the weights that were derived for all the criteria and sub-criteria and using the principles of Alternative Hierarchy Process, derived overall priorities and rankings for the alternatives. Table 3 shows the performance graph provided by the Expert Choice model. This shows that alternative 4 is preferred since it has a priority of 23.7%.

The plant manager stated after seeing the charts:

> We are paid to make the final judgement and have to make the best decision given the age of the unit, goals for the plant and the position of unit #4 on the dispatch list. The charts from the Decision Support System can only guide us, not make the decision for us. Top management is watching how all of us respond to the planned maintenance of this unit given the new competitive pressures facing the company. If we can make this unit work for many more years with minimum maintenance costs, the overall cost of producing power from Crist would be lower compared to the other power plants in Southern Company. That would be a
highly desirable consequence given the pressures of deregulation of the power industry.

Figure 2: An Expert Choice Model for Crist Power Plant

<table>
<thead>
<tr>
<th>Weighting Provided to each Criteria</th>
<th>Final priorities for Each Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>40% RISK</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23.7% for alternative 4</td>
</tr>
<tr>
<td><strong>60% COST</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20.8% for alternative 3</td>
</tr>
<tr>
<td></td>
<td>18.7% for alternative 5</td>
</tr>
<tr>
<td></td>
<td>18.5% for alternative 1</td>
</tr>
<tr>
<td></td>
<td>18.3% for alternative 2</td>
</tr>
</tbody>
</table>

Table 3: Sensitivity Analysis when risk has 40% and cost has 60% of the Weights

**Classification of Crist Case Study as a Multimedia Instructional Material**

The Crist case study could be classified as a multimedia instructional material since it had the following properties:
• The Crist Case Study CD-ROM included 18 pictures, 14 charts, 18 graphs, 27 figures, 15 videos, 2 animations, 4 Powerpoint presentations, in addition to 37 pages of text.

• It provided hands-on experience on using Expert Choice, an expert system used for decision-making.

• Instead of the instructor, the plant manager states the problem and led the students through the case study (videos, audios, photos, animation).

• Provided opportunity for team working and learning from peers.

• Students used multimedia technologies in their presentations (for example, the students were able to show a rotor or expert choice results in their presentation).

Administration of Crist Case Study in the Classroom

The case study and CD-ROM were provided to the students as part of a textbook. During the first week, the competency materials (such as decision making strategies, power industry overview, and overview of expert systems) were taught. During the second week, the CD-ROM case study was shown to the students. With the use of the CD-ROM, the students were shown the problem visually; the plant manager discussed the issues in a video, and assigned the roles to the student groups. Videos of the plant manager and plant engineers led the students to the problem. The visual presentation included a real live plant outage planning and implementation process. Photos, animation, and videos were used to cover concepts of project management, planning, vibration principles, and decision-making. An expert system software, “Expert Choice” was made as part of the CD-ROM and students were able to load and use this software in analyzing the decision model (this was also provided as part of the CD-ROM). Videos, audios, photos, and animation augmented the student's ability to grasp the complex engineering materials and made it possible to apply decision-making theories. The multimedia instructional material provided the
students external links to relevant websites where they could obtain additional information to help them address issues concerning the case study. This was a very important feature, given that students would typically prefer to click on a link rather than go to the library to do research. The main screens used in case study are shown as Appendix A.

The CD-ROM included a tools section that provided the basic competency materials that were needed to analyze the complex engineering and technical problems involved in the decision-making scenario. In addition, a chapter on business ethics was included in the material. Animation, videos, and photographs explained the engineering concepts and made it easy for students to comprehend the concepts of stator, rotor, retaining rings, and other engineering components commonly used in the decision-making situation.

During the second week, the students were divided into teams and assigned roles of MIS managers, engineers, and plant manager. Although a long time subject for debate, Schmidt et al. (2001) persuasively argue that teams make more effective decisions than individuals. The students therefore met in groups to brainstorm and use other teamwork strategies (covered in a class lecture) to come up with findings/solutions to the case study problem in question. Thereafter, the students were required to present their findings in class. The presentations were typically done in a competitive manner such that the different teams challenged each other.

The students were provided results from the Expert Choice Software and in addition were provided ability to work on the decision model itself so that they could perform sensitivity analysis on the problem. Appendix B provides examples of the charts that were incorporated in the case study CD-ROM and also results of sensitivity analysis performed using the Expert Choice software.
The student teams were asked to defend one of the five alternatives and manipulate the expert choice model so that their choice became the best one. The assignment to the students was as follows:

Your group has taken over Mark’s job at Crist Power Plant. As per the current priorities (risk=0.5, cost=0.5), alternative 4 seems to be the most preferred. Your boss prefers alternative 1 and would like you to change the information in the Expert Choice to make alternative 1 the most preferred. Please work with Expert Choice to make this happen and write a note explaining the data that was changed to make it happen. Each group will be given an alternative to defend, change the expert systems to make that alternative come out the best, and discuss the ethical issues to make that alternative attractive. Then, your group would discuss the best and worst options you perceive given that there are no external constraints. Prepare a presentation and write-up.

This assignment provided the students an opportunity to work with the multimedia components of the CD-ROM, include ethical issues in the discussion, and use the Expert Choice software. Occasionally, the plant manager would attend the class presentations and critique the students’ presentations.

**Experimental Design**

A field experiment was conducted in two undergraduate business and engineering classes. The business and engineering departments of this University are separated in different physical locations and the students had no (known) interaction. The students were not told that the multimedia case study would be run at both classes. This further assured no interaction among the students from the business and engineering school. The undergraduate business class was a Management class at the sophomore and junior level. The undergraduate engineering class
was an Engineering Design class at the sophomore and junior level. Historically both courses were taught through the traditional lecture mode using a textbook. Since the purpose of the experiment was to compare and contrast effectiveness of the multimedia instructional materials, the multimedia CD-ROM case study was made part of the course structure.

For both the business and engineering classes, the students were given access to the CD-ROM in a computer lab and as earlier mentioned, they had minimal interaction and were never told, before the experiment, what the other group would be doing during the class time.

**Subjects**

A total of eighty-five students participated in the experiment conducted during the Spring 2000 quarter. Of the eighty-five students, 43 were business students and 42 were engineering students. Most students had no information systems or engineering related work experience.

**Instrument**

Two questionnaires were designed to elicit responses related to the items defined in Table 1. The questions were similar to those used in earlier studies (Hingorani et al., 1998; Goodhue and Thompson, 1995, and Mbarika et al., 2001) thereby reinforcing construct validity. The students were asked to evaluate the effectiveness of the method in understanding a typical issue faced by a manager on a 5-point Likert scale (1 indicating a extremely negative rating and 5 an extremely positive rating). The questionnaire had items that measured the eight Learning-Driven and Content-Driven constructs of quality, locatability, ease of use, learning interest, challenging, timeliness, self reported learning, learned from others and one construct of higher order cognitive skills improvement (Table 1).

The students completed the questionnaires and submitted it along with their written comments. Cronbach alpha was computed for each construct to identify whether the items
belonged together within a construct. There are several opinions on acceptable levels of Cronbach alphas. For example, Nunnally (1967) proposes an alpha of 0.80 and higher, while Treacy (1985) suggests a value of 0.70 or higher. Since all the constructs were based on previous studies and since this is an exploratory study, we expected the values of Cronbach alphas to be well above 0.7.

**Analysis Procedure**

Since all eight constructs could be correlated, it was appropriate to use multivariate data analysis (in this case, a factor analysis) to test the direct and indirect (with Learning-Driven and Content-Driven factors as the intervening variable) relationship between student major and higher order cognitive skills improvement. The path analysis tool used in this study is Amos, a program for specifying, estimating, and testing hypothesized interrelationships among a set of factors. Amos considers and solves for all the relationships simultaneously, unlike linear regression analysis, which solves for each set of relationships individually. Specifically, Amos implements the general approach to data analysis known as structural modeling, analysis of covariance structures, or causal modeling. This approach includes as special cases many well-known conventional techniques, including the general linear model and common factor analysis.

**Results**

The Cronbach alphas were computed for each construct (Table 4). The high values of alphas as shown in Table 4 assured us that the items under the constructs used in this study coalesced adequately to measure the constructs. Scaled values for the constructs were computed by averaging the responses across the items identified as best representing the construct. The
descriptive statistics for each of the constructs differentiated by engineering and business students is shown in Table 5.

Table 4: Constructs and their Cronbach alphas

<table>
<thead>
<tr>
<th>Construct</th>
<th>Cronbach Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>0.73</td>
</tr>
<tr>
<td>Locatability</td>
<td>0.89</td>
</tr>
<tr>
<td>Timeliness</td>
<td>0.83</td>
</tr>
<tr>
<td>Self Reported Learning</td>
<td>0.71</td>
</tr>
<tr>
<td>Learning Interest</td>
<td>0.77</td>
</tr>
<tr>
<td>Learned from Others</td>
<td>0.73</td>
</tr>
<tr>
<td>Challenging</td>
<td>0.67</td>
</tr>
<tr>
<td>Ease of use</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Table 5: Descriptive Statistics for the Business and Engineering students

<table>
<thead>
<tr>
<th>Construct</th>
<th>Mean and s.d. (Business)</th>
<th>Mean and s.d. (Engineering)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Order Cognitive Skills Improvement</td>
<td>4.02 (.44)</td>
<td>3.65 (.86)</td>
</tr>
<tr>
<td>Self Reported Learning</td>
<td>3.66 (.53)</td>
<td>3.58 (.85)</td>
</tr>
<tr>
<td>Learning Interest</td>
<td>3.69 (.75)</td>
<td>3.26 (1.04)</td>
</tr>
<tr>
<td>Learned from Others</td>
<td>4.012 (.48)</td>
<td>3.54 (.81)</td>
</tr>
<tr>
<td>Challenging</td>
<td>4.09 (.41)</td>
<td>3.61 (.84)</td>
</tr>
<tr>
<td>Timeliness</td>
<td>3.99 (.56)</td>
<td>3.52 (.94)</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>3.49 (.49)</td>
<td>3.31 (.75)</td>
</tr>
<tr>
<td>Quality</td>
<td>3.29 (.19)</td>
<td>3.24 (.49)</td>
</tr>
<tr>
<td>Locatability</td>
<td>3.75 (.42)</td>
<td>3.50 (.62)</td>
</tr>
</tbody>
</table>

Identification of the Important Factors
The next task was to identify the important factors that explained the variance better. Table 6 shows the loading of the eight constructs. The values of the eigenvalues and percentage of variance indicate that it may be possible to factor the constructs to a smaller set of factors that could explain the phenomenon under study. The criterion used here is the percentage of variance criterion. This criterion requires interpretation of the cumulative percentage of variance accounted for by the factor solution. The factors explaining a small percentage of the variance are deemed to be of little practical significance. In the social sciences it is common to consider a satisfactory solution as one that accounts for 60% of the total variance.

Table 6: Eigenvalues and percentage of variance for the extraction of component factors.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalues</th>
<th>% of Variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.089</td>
<td>51.114</td>
<td>51.114</td>
</tr>
<tr>
<td>2</td>
<td>1.141</td>
<td>14.260</td>
<td>65.374</td>
</tr>
<tr>
<td>3</td>
<td>.892</td>
<td>11.145</td>
<td>76.519</td>
</tr>
<tr>
<td>4</td>
<td>.524</td>
<td>6.554</td>
<td>83.073</td>
</tr>
<tr>
<td>5</td>
<td>.460</td>
<td>5.749</td>
<td>88.822</td>
</tr>
<tr>
<td>6</td>
<td>.367</td>
<td>4.590</td>
<td>93.412</td>
</tr>
<tr>
<td>7</td>
<td>.279</td>
<td>3.491</td>
<td>96.903</td>
</tr>
<tr>
<td>8</td>
<td>.248</td>
<td>3.097</td>
<td>100.000</td>
</tr>
</tbody>
</table>

In this study, the first two factors in Table 6 account for 65.4% of the variance and their eigenvalues were greater than or equal to 1 leading us to conclude that these two factors could be used to explain the variance of the data (Green et al., 1997). We named these two factors as learning-driven and content-driven based on past research (Mbarika et al., 2001).
Identification of Constructs that Compose the Learning-Driven and Content-Driven Factors

We used an orthogonal VARIMAX factor rotation to see which constructs loaded on the two factors. The rotation converged in three iterations. The results are shown in Table 7. The first factor accounts for 51.1% of the total variance and the second factor accounts for 14.2% of the variance. We called the first factor that includes the constructs of learning interest, challenging, self reported learning and learned from others as "Learning-Driven Factor." The variables quality, locatability, ease of use and timeliness loaded together on the second factor called as "Content-Driven Factor."

Table 7: Rotated Factor Matrix

<table>
<thead>
<tr>
<th></th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning interest</td>
<td>.400</td>
<td>.096</td>
</tr>
<tr>
<td>Challenging</td>
<td>.804</td>
<td>.388</td>
</tr>
<tr>
<td>Self reported learning</td>
<td>.696</td>
<td>.252</td>
</tr>
<tr>
<td>Leaned from others</td>
<td>.751</td>
<td>.289</td>
</tr>
<tr>
<td>Quality</td>
<td>.126</td>
<td>.653</td>
</tr>
<tr>
<td>Locatability</td>
<td>.447</td>
<td>.624</td>
</tr>
<tr>
<td>Ease of use</td>
<td>.239</td>
<td>.702</td>
</tr>
<tr>
<td>Timeliness</td>
<td>.387</td>
<td>.642</td>
</tr>
</tbody>
</table>

Model Fit

The next step was to analyze the research model using the Amos path analysis tool. Figure 3 shows the values of the factor loadings for each possible path and the t-statistic corresponding to that path.

Analyzing the data according to the structural model (Table 8) showed that the model had a good fit. Researchers suggest that multiple measures should be used to assess fit of a model to the observed pattern of correlations in the data. (Fornell, 1993; Hayduk, 1987; Jöreskog and Sorbom, 1989). Some commonly used measures of model fit, based on results from analysis of
the structural model are summarized in Table 8. The $\chi^2$ divided by the degrees of freedom is used as a measure of acceptable fit (Idazak et al., 1988, Brooke et al., 1988). The recommended value ranges from 3 to 5 or less (Carmines and McIver, 1981; Marsh and Hocevar, 1985; Wheaton et al., 1977). The computed value of 3.42 for this measure is below most of the suggested cutoff values. Another statistic is goodness of fit index (GFI), which should be close to value of 1 to indicate an acceptable fit (Meyer and Gallatly, 1988). The value of 0.80 for GFI provides further evidence of good fit. Other measures are presented in Table 8.
Figure 3: Direct and indirect relationship between student major and higher order cognitive skills improvement (the t-statistics are in parentheses).

Where:
X1 = self reported learning
X2 = learning interest
X3 = learned from others
X4 = challenging
X5 = timeliness
X6 = ease of use
X7 = quality
X8 = locatability
E1, E2 and E3 = Error Terms

Table 8: Measures of fit.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Recommended values</th>
<th>Our model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>---</td>
<td>85</td>
</tr>
<tr>
<td>Chi square/degree of freedom</td>
<td>&lt; 5</td>
<td>3.42</td>
</tr>
<tr>
<td>Goodness of Fit Index</td>
<td>Close to 1</td>
<td>0.80</td>
</tr>
<tr>
<td>NFI</td>
<td>Close to 1</td>
<td>.74</td>
</tr>
</tbody>
</table>
**Test of Hypotheses**

Figure 3 presents the results of the factor loadings and t-Statistics used to evaluate the direct and indirect relationship between student major and higher order cognitive skills improvement.

**Test of H1:** The direct relationship between student major and higher order cognitive skills improvement (shown in Figure 3) is not significant. The path coefficient of -.13 is very low and t-statistic (-1.61) is less than the cutoff value of 2.

**Test of H2:** The indirect relationship between student major and higher order cognitive skills improvement is positive and significant for the learning-driven factor. As shown in Figure 2, the path coefficient is 0.29 and t-statistic of 2.14 between student major and this factor. The path coefficient between learning-driven factor and higher order cognitive skills improvement of .98 is high and the t-statistic is 12.19 which is well above the cutoff value of 2. The indirect relationship through the content-driven factor is not significant. The path coefficient is -.27 and t-statistic of –1.08 is not significant for relationship between student major and content-driven factor. The path coefficient of -.11 and the t-statistic is –2.61 portrayed a negative relationship between content-driven factor and higher order cognitive skills improvement.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: There is a direct relationship between student major and higher order cognitive skills improvement.</td>
<td>Not Supported</td>
</tr>
<tr>
<td>H2: There is an indirect relationship between student major and higher order cognitive skills improvement, with learning-driven factor as the intervening variable.</td>
<td>Supported</td>
</tr>
</tbody>
</table>

**Findings and implications**

The results lead to the following findings:
• No significant relationship between student major and higher order cognitive skills improvement for both groups

• Business Students Perceived More Higher-Order Skills Improvement Compared to Engineering Students

• Both Groups Perceived an Improvement in Learning-Driven Factor

• Business Students Valued Learning-Driven Factors more than Content-Driven Factors compared to Engineering Students

We discuss each of these findings next.

**No significant relationship between student major and higher order cognitive skills improvement**

The insignificant direct relationship between student major and higher order cognitive skills improvement shows that it is not the major in itself that accounts for the higher order cognitive skills improvement for both the business and engineering students. This shows that one’s specialty might not be the sole reason for showing interest in solving problems in that specialty. Other factors might play a strong role in this process.

**Business Students Perceived Better Higher-Order Skills Improvement Compared to Engineering Students**

Business students reported better higher-order skills improvement (4.02 versus 3.65) when they used the multimedia CD-ROM compared to engineering students. In addition, they reported that learning-driven factor was a significant reason for this improvement (as shown in Figure 3, Research model). Comparison of the constructs under this factor show that the business students perceived higher value on the constructs than the engineering students (self reported learning: 3.66 versus 3.58; learning interest: 3.69 versus 3.26; learned from others: 4.01 versus 3.54; and challenging: 4.09 versus 3.61). In this regard, among business students,
multimedia was more successful in bringing real life problems to the classroom, teaching difficult management and engineering topics, and transferring theory to practice. Students commented:

I learned that there is more than one way to reach a decision. I felt that using the decision support software greatly strengthened our decision and that a decision should be made using more than just one method.

I enjoy learning about a real-life situation and getting down in all the details. I like finding out the answer and seeing where I went right or wrong.

The thing I liked about doing this case study was the fact that we got to do the project as if it was a real situation in the plant. We had to make graphs and use software to get the results of our presentation, just as if we had to present it to the CEO's of the company. It gave us hands on experience to a real life problem.

These results imply that in order to improve the decision-making performance of businessmen and students, it might be important to incorporate multimedia instructional technologies so that the multicriteria engineering and technical problems are brought out live and interactively.

**Both Groups Perceived an Improvement in Learning-Driven Factor**

A second finding is that both groups of students perceived an improvement in learning-driven factor with business students reporting a significant increase (factor load of .29 with t-statistic of 2.14). The means of the constructs under this factor (as shown in Table 5) are all above 3.5 showing that both engineering and business students perceived improvement in learning-driven factors. The four constructs under this factor, *self-reported learning, learning interest, learned from others, and challenging*, were analyzed further and the findings are as follows.

**Self-Reported Learning**
The mean of self-reported learning was 3.61 for the whole group indicating that the students perceived an improvement in this construct. Self-reported learning was greater with business students than with engineering students (3.66 versus 3.58). In this regard, multimedia improved the business students’ understanding of basic concepts, new concepts, and identified central management and technical issues from the case study. This confirms the finding from Ehrlich & Reynolds (1992) study where they state that multimedia provides an opportunity to reach people with different learning styles, different skills levels, and also offers the potential to reduce the learning curve and accelerate the learning process. Some students commented:

*I think the decision making process that we used here will be useful in future careers. The ranking method of cost vs. risk will also prove useful in the field of engineering.*

*I was very interested in the turbine itself. I have not had any experience with turbines so I found it very interesting learning a little bit about how they work and their parts.*

*Learned a lot about power generation and compatibility and typical concerns of the power industry. Just how closely management and engineering must work together to ensure feasibility.*

**Learning Interest**

The students’ learning interest were enhanced more and drew students’ interest during and after the experimental class sessions. The overall average was 3.55 whereas it was 3.69 for business students versus 3.26 for engineering students. Some students commented:

*I was very interested in the turbine itself. I have not had any experience with turbines so I found it very interesting learning a little bit about how they work and their parts. I was very impressed with the Expert Choice Software. I was amazed at the way decisions can be analyzed by the use of computer programs like this one.*

*I enjoyed learning about the expert system and using it to help in choosing an option. It was nice to be able to graph and compare between the options simultaneously.*

*I enjoyed the videos and picture provided on the computer. I thought they were helpful at making an accurate decision.*
I was interested, impressed, and excited about the software. I had never seen or heard about it before. I am not sure what Crist Power Plant's final decision was, but I wonder if they chose the same alternative as our group.

This finding agrees with the Jonassen, 1989 study which states that multimedia is attention-capturing or engaging to use. Another important observation is that the students discussed technical and managerial issues outside of class. A student commented:

I was impressed with my ability to find outside information and take it into consideration. I was also interested in my progress with learning how to work with new software.

**Learned from Others**

The business students responded that they learned more from others with multimedia than did the engineering students. In this respect the students learned from their group members by discussing and interrelating important topics and ideas. The overall average was 3.81 whereas it was 4.01 for business students versus 3.54 for engineering students. This finding reinforces the past studies where multimedia is shown to increase interaction among students (Adams et al., 1996; Goodrum et al., 1993). Some students commented:

I believe that my thinking is getting better because I am learning how to combine more processes to reach a final answer. As a planner I have thought through and made a decision based on what I think would be good planning for the future of a large company.

I came away from this case study knowing substantially more than I did going into it. There is a great deal of everything that goes into decision-making. The business and technical issues are the main ones, but then those can be subdivided into many parts. Teamwork and good decision-making could easily make or break a plant in today’s economy.

**Challenging**

A reason for the improved perception of the business students’ might be because it challenges their multiple senses and fosters teamwork. The overall average was 3.80 whereas it was 4.09 for business students versus 3.61 for engineering students. Woolf and Hall (1995)
believe that the multimedia approach challenges students to want to learn. DiPasquale and McCabe (1993) argue that multimedia makes students really sit up and focus on what’s going on. Some students commented:

*After completing the case study, I feel like I have become a more valuable asset to a future company. I can incorporate financial, future, and engineering issues and concerns into a decision. Before, I do not think I would have accounted for either short-term future or cost effectiveness. Now, I realize the importance of those issues and have become a better decision maker.*

*I learned that there is not really a right answer and only a better answer. This made me realize that I need to think harder to choose the better decision. I learned how important the engineer’s perspective is to a management type decision. Without an engineer to say that something is going to work, what it costs doesn’t mean anything. If it doesn’t work, it is worthless to the company. This case study has helped me to be both a better engineer and problem solver.*

These findings show that designers of multimedia instructional materials need to include materials that will help enhance these four constructs (self reported learning, learning interest, learned from others, and challenging) in their design.

**Business Students Valued Learning-Driven Factors more than Content-Driven Factors compared to Engineering Students**

The results show that the content-driven constructs were not responsible for the business students reporting higher order cognitive skills improvement. The learning-driven factor was identified as the major intervening variable (path coefficient of .98 and t-statistic of 12.19 in Figure 5).

The responses of business and engineering students to content-driven factors were similar. They stated that the quality of information about power generation (as used in the experiment for this study) was deemed current, up to date, useful, sufficiently detailed, and had the appropriate level of detail by both the business and engineering students. They also
perceived that it was also equally easy to use and locate information presented, and the time to complete a task was approximately the same for both groups. Based on observational data, both experimental groups completed their tasks within the same time range.

In contrast, the business students perceived a higher-level improvement on the constructs of self-reported learning, learning interest, learned from others, and challenging compared to engineering students. The Crist Power Plant case study was highly technical and was primarily developed for use in engineering classes. It was a surprise that business students valued it more than the engineering students in improving their higher-level cognitive skills. Some students comments provide further insight about this finding:

I enjoyed the way this case put us in both the engineering and management points of view and let us decide which was most important to this particular case. By doing this I found that the management point of view was most important here because of the financial situation we were put in with deregulation of power plants.

After completing the case study, I feel like I have become a more valuable asset to a future company. I can incorporate financial, future, and engineering issues and concerns into a decision. Before, I do not think I would have accounted for either short-term future or cost effectiveness. Now, I realize the importance of those issues and have become a better decision maker.

The aspects of the case study, in general, that I like the most is the group work. In the real world you will never work on a project from start to finish by yourself. The case studies give extra practice in group communication and decision making steps.

What surprised me about this case study was the amount of time the group had to put into it, how we got to use the Expert Choice to help us back up our decision and how I think I'm getting better at decision-making.
Limitations, Future Research, and Conclusions

This study evaluates the effectiveness of multimedia instructional materials on analyzing a multicriteria engineering and technical decisions. The results show that business students perceived better improvement of the learning-driven factor which in turn led to improved perception of higher-level cognitive skill development. Based on these findings, one cannot, however, extend such an inference to learning in other disciplines such as education, literature and history. Further research must be done in this area before generalizing these results.

A major limitation of this study is that the results are based on perceived student learning and not actual learning. Future research needs to include measures such as student grades and pre- and post- tests.

Replication of this study with an even larger sample size would improve validity. Also, a longitudinal multi-method study, that involves a variety of data collection approaches, is needed to further confirm that the business students’ higher order cognitive skills was improved with multimedia in analyzing a complex engineering problem. This could involve a follow up on how they perform at their respective jobs after they graduate from college.

Another major area for future research could involve comparing different combinations of the variables such as:

- Text and Multimedia (with the same information and Expert Choice software)
- Engineering students without multimedia and engineering students with multimedia
- Business students without multimedia and business students with multimedia.

Most employees and students resort to popular tools such as Powerpoint presentations to present information that lead to major decisions in companies and in classrooms. The study
shows that this process may not be sufficient and it may be important to develop other tools such as multimedia CD-ROMs in order to communicate complex technical and engineering problems to non-technical management.

In conclusion, this study shows that an indirect relationship between student majors and higher order cognitive skills improvement was accounted for by the learning-driven factor as the intervening variable. It found no direct relationship between student majors and higher order cognitive skills improvement. Therefore, we conclude that when higher order cognitive skills improvement is needed, the development of multimedia instructional materials needs to ensure that the learning-driven factors are included. It is critical for the multi-media instructional materials to be designed so that they are challenging, produce learning interest, provide self-reported learning, and provide opportunities to learn from others.

Acknowledgements: This research was based upon work supported by the National Science Foundation under Grant No. DUE# 9752353, 9950514, and 0089036. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
References


Appendix A
Screens from Crist Power Plant Case Study CD-ROM

Planning a Power Plant Maintenance Outage

As Joe Martin, Plant Manager, you have to choose the actions to be taken on the turbine-generator unit #4 during its planned maintenance next January. It is already May and your team (Joe, Jimmy, and Valerie) has only three months to understand the problems with the unit, identify the alternatives, evaluate them, and choose the best alternatives.

You can understand details of the problems, alternatives, the decision-making process, and your assignment by working with the case study menu. You can obtain background information to work on the case study from the tools menu. The sitemap provides a list of all menus and sub-menus used for this case study.
Alternatives

Snapshot of each alternative:

alternative 1 alternative 2 alternative 3 alternative 4 alternative 5
Decision Making Process

Troubleshooting problems
Discussing problems
Evaluating options

More details on the process:

Introduction to expert systems
The importance of good decisions
Link to expert choice software
Real world decision making

Assignment

You will work on this problem as part of a team and make the final decision assuming the role of Joe Martin, Plant Manager. Your instructor will provide detailed instructions on the assignment. You may be asked to do one of the following:

- The team will defend the alternative assigned by the instructor.
- The team will choose and defend the best and the worst alternative.

Please consider the following factors in making your decision:

- Compare and contrast the alternatives using the project criteria and Expert Choice priority chart.
- Please work with the Expert Choice software and see what happens when you change the priorities and weights.
- What were the critical components of the unit and what is the possible outcome if any of them failed? How does your decision address these problems?
- Suggest innovative methods that may not be mentioned in the case study to solve the problem.
Appendix B
Results of Integrating Expert Choice in the Decision Situation
Results from Expert Choice Software