A Multi–Experimental Study on the Use of Multimedia Instructional Materials to Teach Technical Subjects[1]

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I. Introduction

The introduction will discuss stakeholders' positions on Higher Order Cognitive Skills (HOCS). The stakeholders are educators, students, and employers.

HOCS are skills that go beyond basic comprehension of a problem or concept (Lou et al., 2008; Bradley et al., 2007a, b). They consist of skills such as identification of problems, analysis of issues, figuring out alternatives, evaluating alternatives, and making choices. HOCS include question-asking, critical thinking, system thinking, analytical, decision-making, and problem solving skills.

The traditional teaching approach has been criticized for failure to develop HOCS and problem-solving skills needed by the employers in undergraduate education (Broussard et al., 2007; Mbarika, 2003). This societal dilemma is reflected in many science graduates (e.g. engineering, computer science, and information technology) today. These students lack the problem solving skills sought by contemporary employers, hence creating the need for frameworks, methods, and tools to address this dilemma. Therefore, educators are revamping the curriculum to place emphasis on preparing students to graduate with HOCS (i.e. good decision-making and problem solving skills) so as to enhance their performance in the work environment. Educators are investing a great deal to prepare students to be successful as they go on to enter the workforce, enabling them to become productive, responsible members of society by providing an education that encompasses good decision-making and problem solving skills needed to be qualified managers. There is a continuous search by educators for new approaches that can capture the students' attention and enhance students' attainment of HOCS. The need to create active customized learning environments to capture and hold student motivation and continuous learning desire, for different IT tools, is acknowledged.

Employers and top executives in companies seek employees who possess good decision-making skills in terms of their ability to solve problems in areas such as competitiveness, performance, and sustainability. Rieley and Crossley, (2000) emphasize the need of employees that are above average problem solvers, decision-makers, and team players by the employers. Subsequently, IT tools such as Decision Support Systems (DSS), Expert Systems, and multimedia have been developed to help managers in decision-making (Cole et.al. 2000; Tan & Thoen 2000). Bradley et al.,(2007a) further states that it is critical to provide the students with skills that improve reasoning, problem identification, analysis, criteria specification, integrating and inter-relating content, and problem-solving. Researchers (Guzdial & Soloway, 2002; King, 2000) stress the importance of students' ability to demonstrate HOCS in order to prepare for success in the workforce. In particular, engineering, business, and IT employers expect graduates they hire to possess HOCS. For example, National Aeronautics and Space Administration (NASA) has instituted more aggressive decision-making training after discovering that the second major cause of flight-crew related accidents was decision errors (Dornheim, 2000).

Employers expect students to sharpen their decision-making and problem solving skills and make trade-off decisions that translate technical impact into business. As stated above, graduates have to understand and speak the language of management in addition to making decisions in their technical area of expertise (England, 1998).

The rapid rate at which technology is changing and being adopted today requires that graduates successfully apply and expand their fundamental knowledge of science, technology, engineering, and mathematics (STEM) to be able to solve the world's emerging problems (Kern *et al.,*2007). The authors' further state that the fast-movingandglobal, multidisciplinary industrial environments require engineering and IT graduates to have a new and broader skill set. Therefore, the need for graduates to understand and apply several disciplines to solve complex real life problems, to adapt to new tech-

ABSTRACT

A review of "social experiments" with adoption of multimedia-based technologies in Europe has been reported. But, there has been limited discussion on the value of multimedia instructional materials in technical disciplines. This study combines results from experiments carried out over a period of three years with multiple audiences -- IT managers and students majoring in business and engineering -- to examine if multimedia case studies do improve perceived Higher Order Cognitive Skills (HOCS) and if so, what accounted for such improvements. Among all the experimental groups involved in this study, it was found that participants reported improvements in perceived HOCS, self-reported learning, learning interest, challenges to their thought process, and learning from others.

Keywords: *Multimedia instructional materials, Higher Order Cognitive Skills, Instructional Technologies*

nology and changing situations, to combine ideas to synthesize creative solutions, and to work effectively in cooperative groups or teams while having excellent communication skills is highly recognized. For instance, there is a need for business students to communicate technical skills with ease. In addition, the effect of cooperative learning has been demonstrated to show positive effects on academic achievement, student attitudes, social ability, retention, and self-esteem (Kern *et al.,* 2007). As a result, the significant impact of Information and Communication Technology (ICT) on learning is still being explored.

Background

Educators have the role of preparing students with an education that encompasses HOCS development (i.e. good decision-making and problem solving skills) in order for them to be successful in the workforce (Bradley *et al.,* 2007b; King, 2000; Ennis, 1985; Zoller *et al.,* 2002; Zoller, 1993, 1999). Previous research (Zoller 1999; Zoller and Pushkin 2007) highly acknowledges the need to develop students' HOCS in science education as opposed to 'traditional' algorithmic-based lower order cognitive skills (LOCS), given the science and technology based society in which the students must function. There is a paradigm shift from LOCS teaching to HOCS 'learning'. Successful educational systems use the appropriate technical, business, and communication skills that allow the students to clearly communicate highly technical issues to nontechnical personnel (Lim & Benbasat, 2000; Tucker & McCarthy, 2001). However, the pedagogy of teaching technical concepts and issues remains a challenge in both work and educational environments, especially in the area of developing the students' HOCS. Examples of such pedagogically complex concepts include those taught in areas of engineering and IT such as operating systems architectures, telecommunications, vibration, thermodynamics, satellite technologies, and expert systems. The technical concepts in these subjects are normally difficult to communicate and convey to students, thereby contributing to students' lack of interest, attention and retention in the areas of business, engineering, computer science, and IT.

However, multimedia instructional materials have been recognized for enabling the understanding of complex engineering and IT decision-making situations that require HOCS, which are needed for handling complex decision-making situations (Mbarika et al., 2003). Multimedia is instructional materials that includes one or more forms of media such as graphics, video, animation, images, and sound in addition to textual information (Fetterman, 1997, Beckman, 1996). Multimedia-based instructional materials have been identified as an important tool for managers and students in their efforts to connect and apply classroom theory-based learning with the analysis of real-world problems (Raju and Sankar, 1999; Mbarika, et al., 2003). The use of multimedia case studies to convey real-world technical concepts and applications such as those taught in engineering and IT courses has been advocated increasingly in the educational technology literature (Raju and Sankar 1999; Mbarika et al., 2003b; Bradley et al., 2005). Previous research (Mbarika et al., 2003a; Mbarika, et al., 2001) has proven that the multimedia case study methodology has been validated to exhibit the perceived improvement of students' HOCS. The ability for students' to connect theoretical concepts to solve real world problems and be able to apply the knowledge acquired in class to real life situations is enhanced by the use of multimedia instructional materials. Mbarika (2003) further affirms that the learning driven constructs of learning interest, challenging, self reported learning, learned from others, are significant in explaining the impact of multimedia in improving perceived HOCS. Multimedia instructional materials have also been shown to promote deeper learning (understanding) (Mayer, 1999, 2003; Mayer & Anderson, 1992) which is synonymous with HOCS 'learning' since it amounts to problem-solving transfer (Mayer, 2003). Furthermore, the author states that multimedia learning can be evaluated through situations where the learner's ability to use the material for problem solving, is assessed. Pea (1991) affirms that multimedia instructional materials are important building blocks for developing and conveying students' understanding since they can place abstract concepts in a specific context.

Furthermore multimedia allows for individual differences in preferred sensory channels for learning, allows for coordination of diverse external representations (with distinctive strengths) for different perspectives and is less restricted than written text (Pea, 1991). Liu & Yuan (2005) state that incorporating simulation or multimedia content into instructional materials enhances student understanding and retention. In evaluating previous research, the specific aspects of multimedia instructional materials that contribute to a perceived improved handling of difficult concepts and ideas associated with HOCS improvement have not been addressed. Typically, individual abilities have been emphasized as key to learning these tasks. However, Dillon and Gabbard (1999) suggest that the fit between an individual's learning style and the learning method is also an important consideration. Their study suggests that there is a relationship between multimedia instructional material,
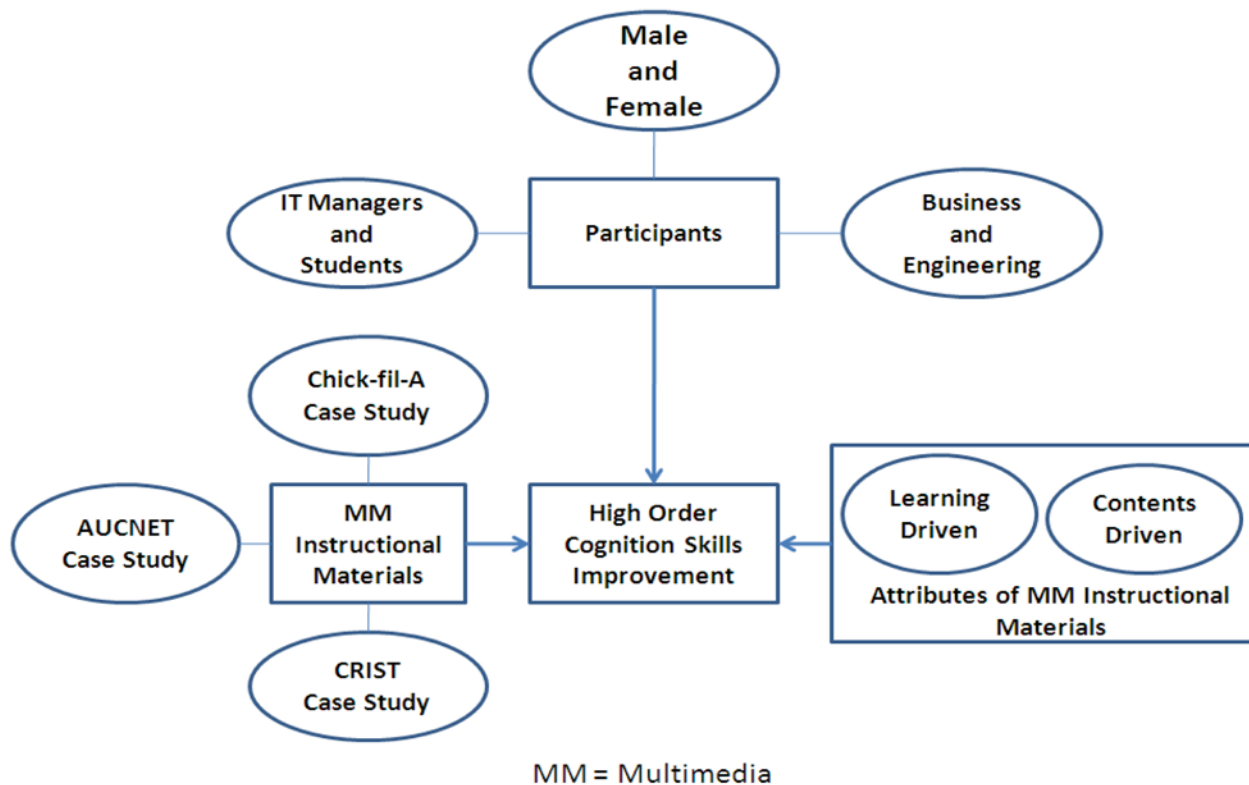
MM = Multimedia

Figure 1: Perceived impact of multimedia instructional materials on HOCS.

learning tasks of the individual, and the learning outcomes. The study aims at answering the research question: "What are the factors responsible for students' perceived improvement of HOCS when using Multimedia case studies?"

In order to fulfill our goal, we have organized the paper as follows: in section II, we discuss the research model used for the studies.. Section III provides a summary of the methodology used in the multimedia case studies. In Section IV, the experimental results and findings are provided. Section V discusses the Business and Academic Implications. Section VI provides Conclusions, limitations, and future research topics.

II. Research Model

The research model presented in Figure 1 shows the impact of multimedia instructional materials on perceived HOCS, the Learner-Driven (LD) factor, and the Content-Driven (CD) factor.

As noted by Hingorani et al., (1998), the LD factor is composed of constructs that show the intrinsic value of the instructional materials to the end user. The constructs that measure the LD factor are labeled as self-reported learning, learning interest, learned from others, and challenging. The HOCS construct was also mea-

sured. The constructs are defined below:

- Self reported learning is used for evaluating whether the case study improved student understanding of basic concepts and whether they learned how to identify central management and technical issues.
- Learning interest is the level of student interest that is generated.
- Learned from others is used to evaluate whether students learned from one another by valuing other students point of view or by interrelating important topics and ideas.
- Challenging is used to evaluate whether the case study brought real life situations into the classroom was helpful in learning difficult management and technical issues and in transferring theory to practice.
- HOCS relate to the perception that an individual has acquired an adequate portfolio of skills to make a decision within a specified period of time (Bradley et al., 2007a, Mbarika et. al., 2003, Hingorani et al., 1998). The authors further state that HOCS 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. The HOCS con-

struct was derived from Hingorani et al. (1998) and includes the following items: identify, integrate, evaluate, interrelate, and problem solving, used to measure it.

Table 1 summarizes the constructs and the items that were used to measure these constructs in the research model.

III. Methodology

a) Participants in Experiment

The case studies were administered in several different classes over a three-year time frame. The participants were segmented into three groups based on the student major (business versus engineering), gender, and work experience. The first group compared learning outcomes of 50 IT managers from a credit card processing company to learning outcomes of 82 students from a major southeastern university. The second group compared learning outcomes of 99 male students to the learning outcomes of 41 female students from a major southeastern university. The third group compared learning outcomes of 43 business student majors to the learning outcomes of 42 engineering students from a major southeastern university.

b) Case Study Procedure

The multimedia instructional materials used in this study were the Crist Power Plant case study, AUCNET USA case study, and the Operating Systems Choices for Chick-fil-A's Point-of-Sales Terminals case study (Sankar & Raju, 2000). Each case study used in this experiment brings real-world problems from business and engineering companies into the classroom. The students were introduced to the case studies during two lecture sessions. The instructors assigned the students teams in which they worked. Each team was required to determine the best alternative by choosing from the different options available to solve the problem at hand. The decision taken had multimillion dollar implications; therefore, the students had to put cost, company mission, and business issues into consideration before choosing an alternative. The teams finally came up with a report and an oral presentation defending their decisions and recommendations. The students then completed the post test questionnaires and indicated how their learning improved in terms of the HOCS and LD constructs. A summary of the case studies and how they were implemented in the classrooms are provided below.

- *Crist Power Plant Case Study:*
This case study illustrates a real live plant outage which emphasized the planning and implementation process for the plant manager. The case study on multimedia CD-ROM introduces the problem to the students with a video of the

Construct	Definition	Items
Self Reported Learning (3 items)	Measure of student's improvement of basic concepts and identification of central management and technical issues through use of case study	Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues (Hingorani et al, 1998).
Learning Interest (3 items)	Measure of the level of student interest generated from the case study	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).
Learned from Others (2 items)	Measure of how much the students learned from each other by valuing other student's point of view or interrelating topics and ideas	Learned to value other students' point of view, learned to inter- relate important topics and ideas (Hingorani et al, 1998).
Challenging (4 items)	Measure of case study's success in bringing real-world issues and problems to the classroom	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).

Table 1: Constructs and items used to measure the constructs

plant manager sharing the problem followed by a thorough explanation of the issues and criteria used to solve the problem. The manager discussed the problem and provided the assignment to the students. The students assumed the role of a plant manager working with an expert system to refine their decisions and chose among multiple alternatives for maintaining a turbine-generator at a power plant to solve the $2 million problem. The students analyzed and solved the problem. They presented their findings using a PowerPoint presentation and provided a written report. The concepts covered are project management, planning, vibration principles, and decision-making. The instructional materials included the following multi-media components: videos, audios, photos, and animation. These components augmented the student's ability to grasp the complex business and engineering materials and made it possible to apply theories they had learned in other classes to solve the problem. Figure 2 (a) and (b) illustrates photos used on the main screen of the Crist power plant case study. As shown in this figure, many of the screens were accompanied by a video. Students had the option to play the video or read the text version of the case study related to that screen.

• *Chick-fil-A Case Study:*

This case study illustrates the management decisions Chick-fil-A faced as the organization prepared to move from its current Point-Of-Sales (POS) system to a choice between two operating systems. The two POS systems were based on Windows NT and Windows CE technology. Students assumed the role of a Management Information Systems executive who had to choose between two operating systems for use as the company's POS system. The students worked in teams and each team had to determine which operating system was a better choice. The concepts covered were operating systems, business-technology alignment, joint application development process, and user interface issues. Since the Chick-fil-A chain operates over 700 corporately owned stores, this changeover had an impact of approximately $3.29 million investment. Each team had to take the following into consideration as it made the decision (a) the mission of Chick-fil-A; (b) depreciation of existing systems; (c) projected return on investment of new systems; (d) total cost of ownership of existing and new systems; (e) employee retention, training, and education; (f) alignment of Chick-fil-A's IT Strategy and Business Strategy; (g) competitive advantage;
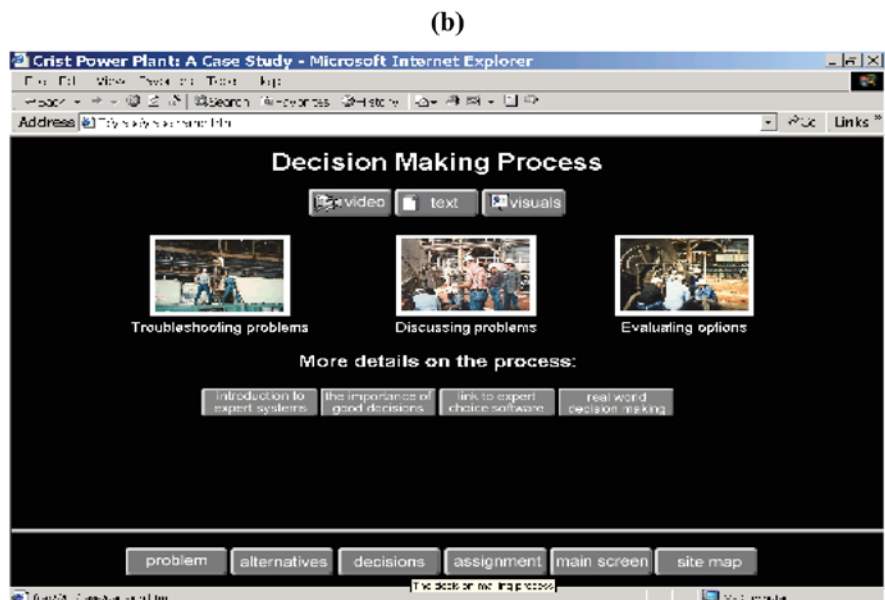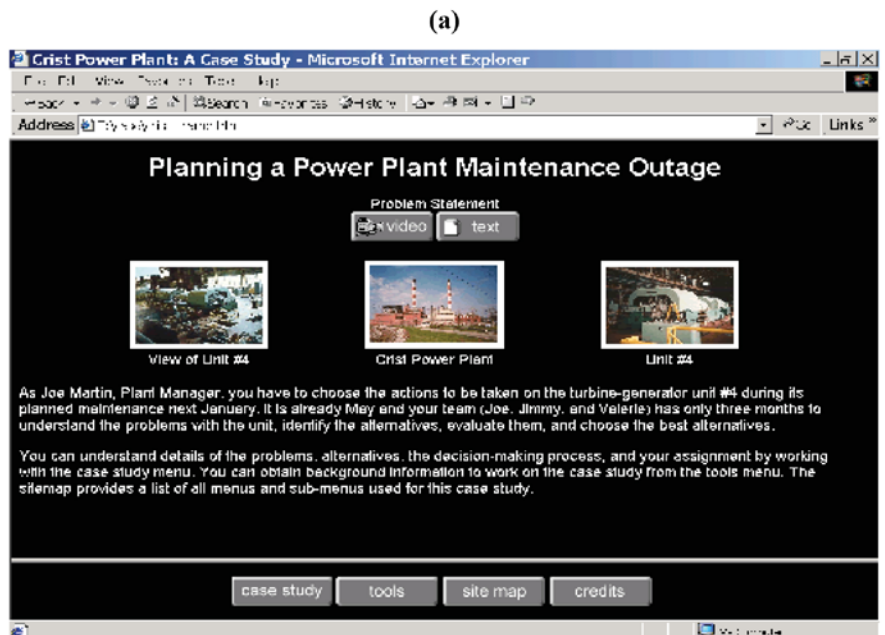
Figures 2: Snapshots of Screen Design: (a) Power Plant Planning; (b) Decision Making

and (h) Chick-fil-A's critical success factors. In addition to this, a tutorial provided background information on Windows CE and NT. The team had to write a report and give an oral presentation explaining their decision and recommendations. After the students completed the case study, they completed a questionnaire that measured the HOCS construct. The items used to measure the perceived improvement of HOCS construct for the Chick-fil-A case were:

- I improved my ability to *identify* operating and information system issues.
- I improved my ability to *integrate* operating and information system issues.

- I improved my ability to *evaluate critically* operating and information system issues.
- I learned to *interrelate* important topics and ideas.
- I learned to *solve problems* based on business theories.

Students were asked to rate their agreement with the items above on a 5-point Likert scale ranging from 1, *strongly disagree*, to 5, *strongly agree*.

- *AUCNET USA Case Study:*

Students took on the role of managers for this on-line auto auction company. They had to choose between a satellite network based on low earth orbiting or a network based on internet technologies. Upper management was concerned that the e-commerce company had not made a profit since its inception and was dependent on capital infusion from AUCNET Japan to function. The number of dealers had dropped from 700 (at the peak) to 300. The concepts covered were entrepreneurship, e-commerce technologies, strategic planning, satellite technologies, and internet technologies.

c) Instruments Development

The Knowledge Test was used for collecting data dealing with the content covered in the case study. The Knowledge Test was used for pre- and post-testing to assess prior knowledge and learning gains. A 40 item student attitude questionnaire was also administered before and after the case study. It dealt with attitudes in several areas: general attitude toward subject matter, relevance to life and society, impact on cognitive domain of learning, impact on positive aspects of affective domain, impact on negative aspects of affective domain, impact on teamwork, demographics and communication skills. Students reported their attitudes in these areas in relation to each question using an A-to-E Likert-type response scale where A = "Strongly Disagree" and E = "Strongly Agree". The multi-item questionnaire was developed to evaluate whether the case study (a) successfully brought real life problems to the classroom, b) was helpful in learning difficult management and engineering topics, and c) was helpful in transferring theory to practice. These are very important concepts to evaluate considering the many challenges that instructors encounter in bringing real world problems to the classroom in a manner that can be grasped by the students. The questions were similar to those used in earlier studies (Hingorani et al., 1998; Goodhue and Thompson, 1995, and Mbarika

et al., 2001, 2003) thereby reinforcing construct validity. Participants were asked to evaluate the effectiveness of the multimedia case studies in understanding real life problems faced in the work environment, difficult management and engineering concepts, and application of theory into practice. The students' perceived HOCS improvement was measured. The questionnaire also consisted of items that measured the constructs of learning interest, challenging, self reported learning, learned from others and Perceived HOCS improvement, please refer to Table 1.

IV. Results

The Statistical Package for the Social Sciences (SPSS), a computer program, was used to analyze data. The t-test was used to compare the means of the pre and post achievement tests in order to analyze knowledge assessment. To compare the results of each pre and post category, a paired-sample correlation and descriptive on the attitude survey results were run. During the analysis phase, the multiple regressions model was used to investigate the nature and extent of the relationship between the intervening variable (i.e. students' majors, gender, work experience, and their perceived improvement of HOCS). Cronbach's alpha was

	Experiment 1 (Chick fil A Case Study administered within a one-year period)		Experiment 2 (CRIST Case Study administered within one and a half year period)		Experiment 3 (AUCNET Case Study administered within a three- year period)	
	Mean (s.d.) IT Managers	Mean (s.d.) Students	Mean (s.d.) Business	Mean (s.d.) Engineering	Mean (s.d.) Female	Mean (s.d.) Male
Higher Order Cognitive Skills Improvement	3.48 (.67)	4.19 (.52)	4.02 (.44)	3.65 (.86)	4.00 (.52)	3.70 (.60)
Self Reported Learning	3.59 (.70)	4.20 (.47)	3.66 (.53)	3.58 (.85)	3.80 (.67)	3.61(.66)
Learning Interest	3.36 (.71)	3.68 (.64)	3.69 (.75)	3.26 (1.04)	3.00 (.85)	3.20 (.82)
Learned from Others	3.66 (.75)	4.12 (.66)	4.012 (.48)	3.54 (.81)	3.97 (.56)	3.73 (.67)
Challenging	3.61 (.72)	4.16 (.51)	4.09 (.41)	3.61 (.84)	4.01 (.58)	3.78 (.65)

Table 2: Descriptive Statistics for the Participants in the different experiments [2]

[2] Questionnaire administered using a 5-point Likert scale, 1 indicating an extremely negative rating and 5 an extremely positive rating.

used to assess the internal consistency or reliability of the scales designed to measure the constructs used in this study. The values of 70% and higher are acceptable levels of Cronbach's alpha (Treacy, 1985). The results from the analysis of the student responses are provided in Table 2. The means and standard deviations for all three experiments are shown in this table. The value of the mean for all of the constructs is above 3 (neither agree nor disagree) showing that the students perceived improvement in all the constructs irrespective of the group that they belonged. In addition, the difference between the following groups and constructs was significant at a 0.01 level.

___Figure 3 (a), (b), and (c) shows the mean values of the constructs for the three experiments presented in Table 2 above.

Findings

a) Self-Reported Learning

The results indicate that IT managers and all experimental student groups perceived an improvement in their self-reported learning by using the multimedia case studies. This is well illustrated by the mean values in Figure 3. This suggests that the multimedia instructional materials improved participants' understanding of basic concepts, new concepts, and helped them to identify central management and technical issues from the case study. Furthermore, the findings of this study support those obtained in Ehrlich & Reynolds (1992) study in which it is stated that multimedia provides an opportunity to reach people with different learning styles, different skill levels, and also offers the potential to reduce the learning curve and accelerate the learning process. Reinforcing these findings, some survey participants — IT managers and all the experimental students' groups—commented:

"I practiced breaking down a problem situation and looking at all component aspects of the problem including costs vs. risks, materials available, and use of resources to make an intelligent decision on how to treat the situation at hand. I learned that a new product may not always be the correct choice based on compatibility issues and cost analysis vs. functionality."

"I learned about the many different risks that are involved in making decisions. It is helpful information to use when making any kind of engineering decision."

"Currently, I work at the IT Help Desk and I can tell how much the class has affected my work. I am able to speak about the technical aspects
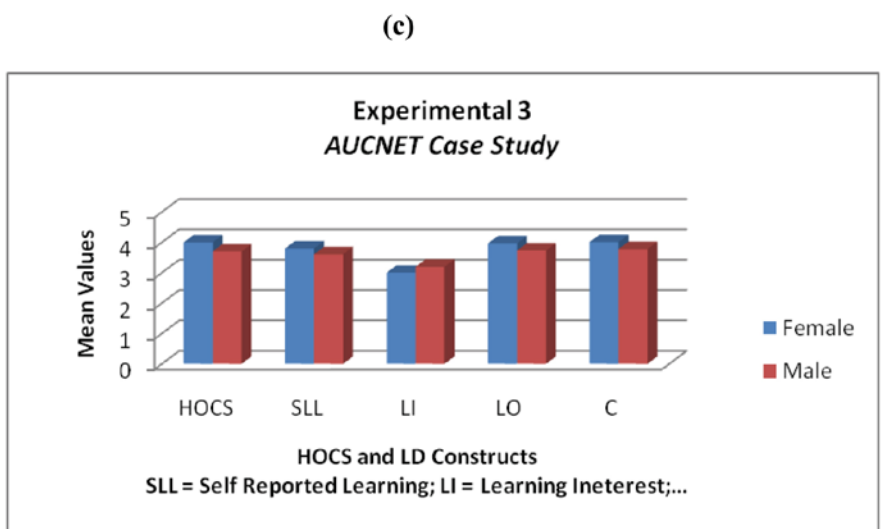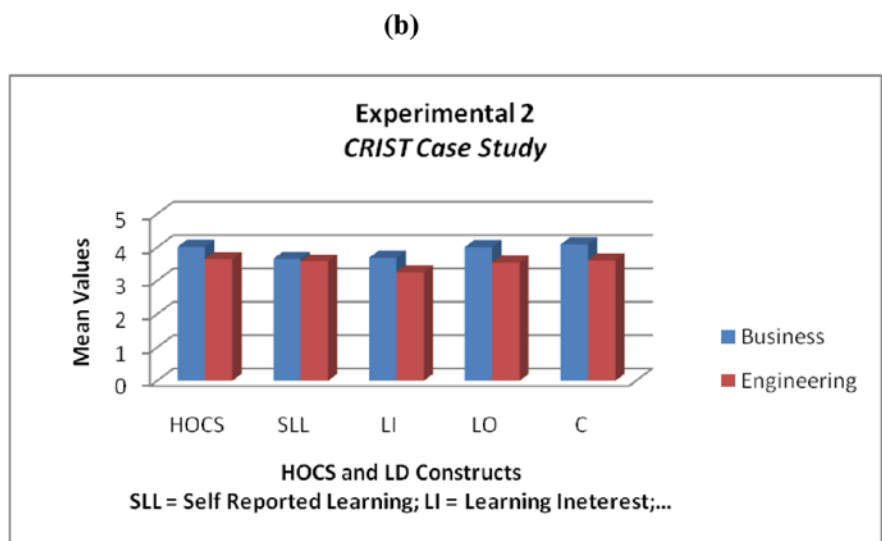

(a)

Experimental 1
Chick fil A Case Study

HOCS and LD Constructs
SLL = Self Reported Learning; LI = Learning Ineterest; LO = Learnning from Others; C= Challenging

(b)

Experimental 2
CRIST Case Study

HOCS and LD Constructs
SLL = Self Reported Learning; LI = Learning Ineterest;...

(c)

Experimental 3
AUCNET Case Study

HOCS and LD Constructs
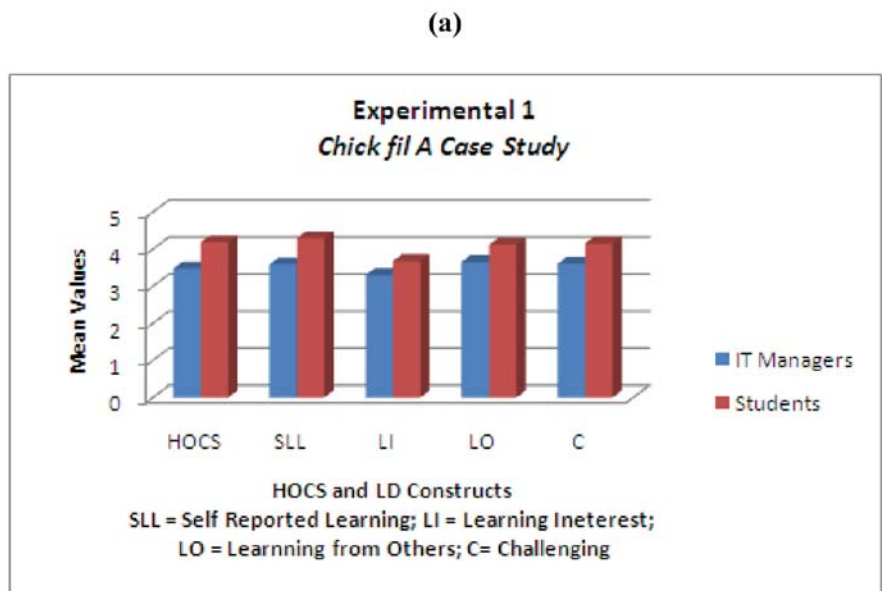SLL = Self Reported Learning; LI = Learning Ineterest;...

Figure 3: Mean Values of Constructs used in the Experiments: (a) Chick fil A Case Study; (b) CRIST Case Study; (c) AUCNET Case Study

with others and understand what they are talking about. I'm not sure specifically how I could use the information I'm learning today for my future career. Technology changes so rapidly that what I learn today may not be the way it is done in the future. However, this material is giving me the foundation I need to build on so that I'll be ready for the next change. This has been the most informative and fun learning experience I have had in my college experience."

"I learned how to use the available technology to solve business problems. I feel more confident now when it comes to talking to others about the specifics of telecomm."

b) Learning Interest

The perceived learning interest of the IT managers and all the experimental students' groups was more enhanced and the participants' interest during and after the experimental class sessions was sparked. This is well illustrated by the mean values in Figure 3. Some of the participants commented as follows:

"I find the material relatively simple to understand. Keeps me interested in learning more about current and past issues.
I have enjoyed working on an actual problem. This really keeps me interested because I see the theories that I learn in school applied in a practical environment."

"I also enjoy the simulated responsibility of studying the problem from different points of view, and from the information given, generating questions and at least forming a personal opinion on how the situation should be handled."
"I was very interested and impressed by the Expert Choice software used in analyzing the various options. I had never previously seen such a decision-making aid."

"I enjoyed learning about how the telephone systems work. It's fascinating to see how it works and most of the time we don't even think about it – we just take it for granted."

"I thought that the material was very interesting and related well to the technology we are already familiar with."

"Keeps me interested in learning more about current and past issues."

"I enjoy all of it, it is going to be my career and I enjoy learning."

These findings agree with the Jonassen, (1989) study, which states that multimedia is attention capturing and engaging to use. Another impor-

tant fact associated with enhancing learning interest is that the authors observed that the IT managers and the students discussed technical and managerial issues even after the case study sessions; a rare occurrence indeed in academic settings where students get bored quickly with topics and lectures.

c) Learned from Others

The IT managers and all the experimental student groups perceived that they learned from others with the multimedia instructional materials during their group interactions. This is well illustrated by the mean values in Figure 3. In this respect their perception relates to learning from their group members by discussing and interrelating important topics and ideas. The findings reinforce past studies which indicated that multimedia increased interaction among students (Adams et al., 1996; Goodrum et al., 1993). Some students commented:

"I have learned to be more open to new material and ideas and really learn from them.
I feel that through understanding the material I had to look at problems from every angle and even listen to others' viewpoints in order to solve the problem. I feel I have become better at problem solving."

"I also enjoy the simulated responsibility of studying the problem from different points of view, and from the information given, generating questions and at least forming a personal opinion on how the situation should be handled."

Majority of the students enjoyed learning from others as they worked with the instructional materials as can be noted by their following comments:

"As I worked with my group, they brought up ideas, viewpoints, and questions that I had not thought of myself. This helped to quickly expand my knowledge of the case and develop a defense for our chosen method to solve the problem at hand."

"When engineers work together, it seems that the product is more than the sum of the individuals. I think I'm starting to learn just how powerful a few motivated engineers can be when they work together."

"I enjoyed hearing my group's points on which one they think is the best, worst and why. It was interesting to hear what they had to say and why they chose which options. It was interesting to see how different people come out with different ideas even though we all read the same thing."
"While working on the presentation, I learned

that working with a group gives new perspectives at the topic. There are many different ways of looking at something and many solutions to problems as well."

"…the most enjoyable aspect to the case study is the group work that is involved with the case study participation."

d) Challenging

The IT managers and the students perceived that the material was challenging and fostered teamwork. 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:

"I enjoy learning about the material that is presented to me because it stimulates my thinking which makes me think that I'm in the right major."

"I enjoyed the challenge of the case study. One of the reasons I chose to become an engineer is because I love challenges. Challenges are sometimes the best way to learn."

"It was difficult to decide which option would be best. There were enough missing variables that we did not have complete information about that made the decision tough, i.e. the condition of the spare stator bars. The number of options also made it challenging."

These findings indicate that designers of instructional materials for difficult technical and engineering subjects, whether in an academic or business-related environment, need to include materials that will help enhance self reported learning, improve learning interest, provide opportunities to learn from others, and challenging learning.

V. Discussion: Business and Academic Implications

The findings show that multimedia aids in development of students' perceived HOCS. This concurs with Mbarika's et al., (2003) findings that multimedia instructional materials have a positive influence on LD factors. In light of rapid technological developments the effectiveness of instructional design hinges upon increasing cognition of complex concepts for improved and faster decision-making. Not only is there evidence that computerized multimedia instruction is important to cognition in terms of time, one study indicated a 88% reduction in learning

time (90 minutes versus 745 minutes) (Kulik, et al, 1983), but also in terms of effective delivery of complex information. A study by Mayer (1993) found that multimedia instruction provided individuals with low prior domain knowledge ability to build cognitive models of systems. These findings suggest important ramifications for use and development of multimedia-based instructional materials as an aid in development of perceived HOCS. Multimedia-based learning and decision-making tools were found to help in development of other perceived skills such as challenging, learning interest, learning from others, and self-reported learning. These results have implications for organizations and learning institutions pertaining to:

- Adapting to different learning styles, and
- Enhanced and increased group-collaboration.

Adapting to Different Learning Styles

Various people have different learning styles and an individual's method of learning can be an important consideration when developing a learning environment (Fahri et al, 2001). Multimedia-based learning addresses the issue of different styles of learning by providing different methods of presenting the information. Soloman's (1992) learning styles inventory develops a typology of different ways students learn. The typology classifies learning types into four categories: input, processing, perception, and understanding. Input varies between using visual or verbal information. Processing involves the physical (active) or mental (reflective) manipulation of the information provided. Perception is driven by sensing (observation) or intuition (reasoning). Understanding involves a sequential (linear step-based approach) or global (ultimate objective driven) approach. The diversity of learning styles is exhaustively examined by Soloman (1992) who found that majority of students are active processors, driven by sensing, prefer visual input, and find sequential learning to be more coherent. For example, individuals who learn by watching or seeing may focus more on videos, graphics and animation. Learners that focus more on feeling and doing can also benefit from watching video and sound in which they can view actions and see and hear the feelings of the subjects in the context of the problem situation. Yet, as Felder and Silverman (1988) pointed out, there exists little pedagogical support that addresses the diversity, calling for newer and more effective tools and techniques to enhance the learning process across the diverse styles. In that aspect, multimedia seems to emerge as a potential candidate of

choice to help students with different learning styles. This is reinforced by the findings from our study where IT managers or students, business or engineering students, males or females responded favorably to all the case studies even though it was implemented in different classrooms by multiple instructors.

By adapting to learning style, multimedia instructional materials might motivate and encourage students to enter fields such as business or engineering. It may also help increase the diversity in male-dominated fields by increasing understanding and competency and lessening some of the limitations of text-based learning materials that one group may encounter over another. This may help in attracting and retaining individuals who may find technical fields to be boring and difficult to learn or where they may feel pressures from stereotypical feelings of inferiority. Females and other under-represented groups in fields such as engineering, IT and computer science may be encouraged to pursue these fields if different approaches are used to present the instructional materials that are more amenable to their learning styles for mastery of the subject matter. It is possible that multimedia instructional materials might balance the gender inequalities found in many countries: such as in India where the current base of IT professionals is 85% males and 15% females; United States where the technology workforce consists of 71% males and 29% females. This might also lead to the development of more multimedia-based training materials in order to foster self-motivated, self-paced and continuous learning by future employees or students.

Enhanced and Increased Group Collaboration-based Learning

Recognizing the value of multimedia can be beneficial to the employees of companies since they can increase the growth of organizational knowledge by encouraging knowledge sharing and collaboration. The emergence of digital audio and video technologies that can computationally compress, manipulate, and transmit content over distributed communication networks has brought the world closer. In addition, steady technological innovations and infrastructure developments, especially increased bandwidth availability, are augmenting developments in remote collaboration (Gale, 1992). Gale found out that the collaborator's (learner's) perception of productivity significantly increases with the availability of multimedia technologies. Two trends are fueling the prom-

ise of multimedia as a ubiquitous learning technology: (1) the fact that multimedia allows for both synchronous and asynchronous collaboration; (2) the growth of broadband Internet as a potential delivery medium. Altogether the facts point towards vast improvements in cooperative enquiry (Bargeron, et al. 1999).

The recognition that multimedia can help improve an individual's learning can encourage more group-oriented efforts where individuals may collaborate with others in making critical decisions pertaining to issues such as project management, product design, marketing promotion, and customer or supplier decisions. This could have cost-saving implications through the efficient use, retention, and sharing of knowledge.

Although technical improvements in the production of learning materials do not infer pedagogical efficiency, it does move acquisition of knowledge a step close to the learner. Pedagogical efficiency then becomes a function of content effectiveness rather than content delivery. The learning scenario is transformed from a static rule-based one-way control to a much more learner-empowered, interactive and dynamic environment. The rich interaction and adaptability that is imperative for learning technical subjects might be satisfied through the use of multimedia. No longer captive to the static delivery of didactic content, technical education, teachers can concentrate on exploring new and relevant content pointing to the needs of the learner.

VI. Conclusions, Limitations, and Future Research

This study evaluates the effectiveness of multimedia instructional materials in conveying technical issues to IT managers and students from different backgrounds with different subject majors, gender, and work experience. The results show that the IT managers and the students who participated in multimedia case study exercise perceived improvement of their HOCS. The results from this study maintain that the traditional lecture methodology is not sufficient in presenting complex engineering and technical information and it is important to develop tools such as multimedia instructional materials that can provide students with the ability to bring real-world issues into classrooms. For the learning process to be effective the audience needs to be challenged and provided with opportunities for learning from self and from others. If this study is replicated in other settings,

it may identify the need to create a wider set of multimedia instructional CD-ROMs that could be used to communicate complex IT and engineering problems to students. The positive results from this study and the findings from the literature indicate that it is critical that multimedia instructional materials be developed for further use in technical and engineering fields to bring real-world issues into classrooms. The improvement in the learning is also attributed to team work and interactive learning through multimedia.

One of the limitations of the studies above is that only perceptual measures of HOCS improvement were identified (Raju et al., 2004); therefore, the researchers restricted the study to measuring students' perceived HOCS improvement. Bradley et al., (2007a) cite the difficulty in measuring actual learning and the limited number of instruments available to measure actual learning. Therefore the ability to measure actual learning using multimedia instructional materials remains a challenge for future research.

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