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December 2001

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### Recommended Citation

Mbarika, Victor; Sankar, Chetan; and Raju, P., "An Interplay of Gender and Multimedia Instructional Materials on Enhancing Higher-Order Cognitive Skills" (2001). *AMCIS 2001 Proceedings*. 11.  
<http://aisel.aisnet.org/amcis2001/11>

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# AN INTERPLAY OF GENDER AND MULTIMEDIA INSTRUCTIONAL MATERIALS ON ENHANCING HIGHER-ORDER COGNITIVE SKILLS

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## Abstract

*This research investigates the perceptions of female versus male 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, female and male, participated in an experiment where they analyzed two case studies 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 female students being the experimental group and male students as a control group. The major findings are: no significant relationship between gender and higher order cognitive skills improvement, female students perceived more higher-order skills improvement compared to male students, both groups perceived an improvement in learning-driven factor, and female students valued learning-driven factors compared to male students. These results show that multimedia instructional materials were found to be very helpful in making multicriteria engineering and technical decisions. In particular, they were more effective for female students if they included learning-driven factors such as challenging the participants, providing self-learning opportunities, making it possible to learn from others, and enhancing learning interest.*

**Keywords:** Multimedia, gender, learning, case study, engineering

## Introduction

Multi-media instructional materials have been identified to be helpful to managers understand complex engineering decision-making situations (Raju and Sankar, 1999; Mbarika, et al., 2001). Researchers disagree over what impact multimedia has on a person's higher order cognitive skills improvement (Dillon and Gabbard, 1999). Higher-level cognitive skills implies the ability to identify, formulate, integrate, evaluate, interrelate concepts, develop choices, and make a decision.

Researchers also argue persuasively that to look at user interaction with information technology (multimedia included) the gender of the user should be taken into consideration. Gefen and Straub (1997) argue that women and men differ in their perceptions of information technology. The same study suggests that managers and co-workers, moreover, need to realize that the same mode of communication may be perceived differently by the sexes, suggesting that more favorable communications environments might be created, environments that take into account not only organizational contextual factors, but also the gender of users. Repeatedly, research has shown that females have more negative attitudes toward computers (information technology) than males (Busch, 1995; Levin & Gordon, 1989; Shashaani, 1994). These negative attitudes may affect interactions of females with computers and explain the decreasing number of females in technical careers (Taylor and Mounfield, 1994). Many studies provide evidence that females and males are different in perceiving multimedia information (McGee, 1979; Peter, et al., 1995; Chanlin, 1999). However, Van Strein and Bouma (1990) criticizes gender differences in visualization is insignificant and difficult to detect. Given these general findings, gender-specific attitudes should be considered when designing learning environments that use some form of information technology (Proost and Elen, 1997).

Therefore, we formulated the following research question: Given complex engineering and technological decisions that students have to deal with in their career, does the interaction of multimedia instructional material with the student's gender have an effect on their higher-level cognitive skills?

This paper answers this question by reporting the results of an experiment conducted with female and male students. 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 engineering 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 to identify the constructs and factors that need to be considered. Two groups of students, female and male 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 items. A structural equations model was developed in order to test the research hypothesis with male students being the experimental group and the female students as a control group. The results of the experiment reveal significant findings on the ability of multimedia instructional materials to improve higher-level cognitive skills of female students. This leads to a series of recommendations and future research topics.

## 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 female and male students to see if multimedia case studies could improve students' higher order cognitive skills. A research model was developed to answer the research questions:

1. Is there a direct relationship between gender (female versus male) and higher order cognitive skills improvement?
2. Is there an indirect relationship between gender (female versus male) and higher order cognitive skills improvement with any intervening variables?

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

**Table 1. Constructs and Items Used to Measure Learning-Driven and Content-Driven Factors**

Construct	Items
Self Reported Learning (3 items)	Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues. (Hingorani et al, 1998, Mbarika et al., 2001)
Learning Interest (3 items)	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, Mbarika et al., 2001)
Learned from Others (2 items)	Learned to value other students' point of view, learned to inter- relate important topics and ideas. (Hingorani et al, 1998, Mbarika et al., 2001)
Challenging (4 items)	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, Mbarika et al., 2001)
Timeliness (2 items)	Task completed on time, case study reports delivered on time. (Goodhue and Thompson, 1995, Mbarika et al., 2001)
Ease of use (3 items)	Easy to learn, easy to use, had enough training to use the case study. (Goodhue and Thompson, 1995, Mbarika et al., 2001)
Quality (6 items)	Current, up to date, needed data, useful, appropriate level of detail, sufficiently detailed. (Goodhue and Thompson, 1995)
Locatability (4 items)	Easy to find, easy to locate, obvious, exact definitions of terms were available. (Goodhue and Thompson, 1995)

## Research Methodology

The hypotheses were tested by administrating a field experiment in several classes 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*

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). The objectives of the Crist case study were to teach the students:

- (a) the technical and project management details involved in planning and implementing a real-world project,
- (b) the importance of developing and prioritizing project criteria in analyzing alternatives, and
- (c) embedding an expert system in the decision-making process.

A CD-ROM was created in order to show the problem to students (Sankar and Raju, 2000). 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.

### *Experimental Design*

A field experiment was conducted in two undergraduate business and engineering classes.

**Subjects:** A total of 137 students participated in the experiment conducted during the Winter and Spring 2000 quarter. Of the 140 students, 41 were female and 99 were male.

**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).

### *Results*

The Cronbach alphas were computed for each construct. The alphas were *0.96 for quality*, *0.89 for locatability*, *0.78 for timeliness*, *0.66 for ease of use*, *0.78 for Self reported learning*, *0.83 for learning interest*, *0.81 for challenging*, and *0.71 for learned from others*. The alpha for *higher order cognitive skills* was *0.86*. These high values of alphas assured us that the items under these constructs 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 female and male students is shown in Table 2.

**Table 2. Descriptive Statistics for the Female and Male Students**

	Mean (Female)	Mean (Male)	Std. Deviation (Female)	Std. Deviation (Male)
Higher Order Cognitive Skills Improvement	4.00	3.70	.52	.60
Self Reported Learning	3.80	3.61	.67	.66
Learning Interest	3.00	3.20	.85	.82
Learned from Others	3.97	3.73	.56	.67
Challenging	4.01	3.78	.58	.65
Timeliness	3.87	3.67	.76	.79
Ease of Use	3.55	3.45	.76	.69
Quality	3.51	3.36	.48	.56
Locatability	3.64	3.52	.64	.58

### *Identification of the Important Factors*

In this study, two factors account for 60.43% 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). We called the first factor that includes the constructs 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."

### *Model Fit*

The next step was to analyze the research model using the Amos path analysis tool. Analyzing the data according to the structural model showed that the model had a good fit. Figure 1 shows the research model with the path coefficients and t-statistics.

**Table 3. Results of Testing Hypothesis**

Hypothesis	Results
H1: There is a direct relationship between gender and higher order cognitive skills improvement.	Not Supported
H2: There is an indirect relationship between gender and higher order cognitive skills improvement, with learning-driven factor as the intervening variable.	Supported

## **Findings and Implications**

The results lead to the following findings:

- No significant relationship between gender and higher order cognitive skills improvement
- Female students Perceived More Higher-Order Skills Improvement Compared to Male students
- Both Groups Perceived an Improvement in Learning-Driven Factor
- Female students valued Learning-Driven Factors more than Content-Driven Factors compared to male students

We discuss each of these findings next.

**No significant relationship between gender and higher order cognitive skills improvement.** The insignificant direct relationship between gender and higher order cognitive skills improvement shows that it is not the student gender in itself that

accounts for the higher order cognitive skills improvement for both the female and male students. This shows that one's gender might not be the sole reason for showing interest in solving problems using multimedia instructional materials. Other factors might play a strong role in this process. The results show that learning-driven factor is important in improving the higher-level cognitive skills of both the female and male groups.

**Female Students Perceived Better Higher-Order Skills Improvement Compared to Male Students.** Female students reported better higher-order skills improvement (4.00 versus 3.70) when they used the multimedia CD-ROM compared to male students. In addition, they reported that learning-driven factor was a significant reason for this improvement. Comparison of the constructs under this factor show that the female students perceived higher value than the male students for all constructs except the 'learning interest' construct (self reported learning: 3.80 versus 3.61; learning interest: 3.00 versus 3.20; learned from others: 3.97 versus 3.73; and challenging: 4.01 versus 3.78). In this regard, among female students, multimedia was more successful in bringing real life problems to the classroom, teaching difficult management and engineering topics, and transferring theory to practice. This result implies that in order to improve the decision-making performance of businessmen and students, regardless of their gender, 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 female students reporting a significant increase (factor load of .20 with t-statistic of 2.00). The means of the constructs under this factor, (as shown in Table 5) are all above 3.5 showing that both female and male students perceived improvement in learning-driven factors. The only exception was the 'learning interest' construct that had means of 3.20 and 3.00 for the female and male student groups respectively (on a scale of 5 as earlier mentioned).

**Female students Valued Learning-Driven Factors more than Content-Driven Factors compared to Male students.** The results show that the content-driven constructs were not responsible for the female students reporting higher order cognitive skills improvement. The learning-driven factor was identified as the major intervening variable (path coefficient of .99 and t-statistic of 13.13 in Figure 1). The female students perceived a higher-level improvement on the constructs of self-reported learning, learning interest, learned from others, and challenging compared to male students. The Crist Power Plant case study was highly technical and was primarily developed for use in engineering classes. It was a surprise that female students valued it more than the male students in improving their higher-level cognitive skills.

## Conclusions, Limitations, and Future Research

This study evaluates the effectiveness of multimedia instructional material on conveying a multicriteria engineering and technical decision to female and male students. The results show that female students perceived more improvement of the learning-driven factor, which in turn led to improved perception of higher-level cognitive skill development.

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 female 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.

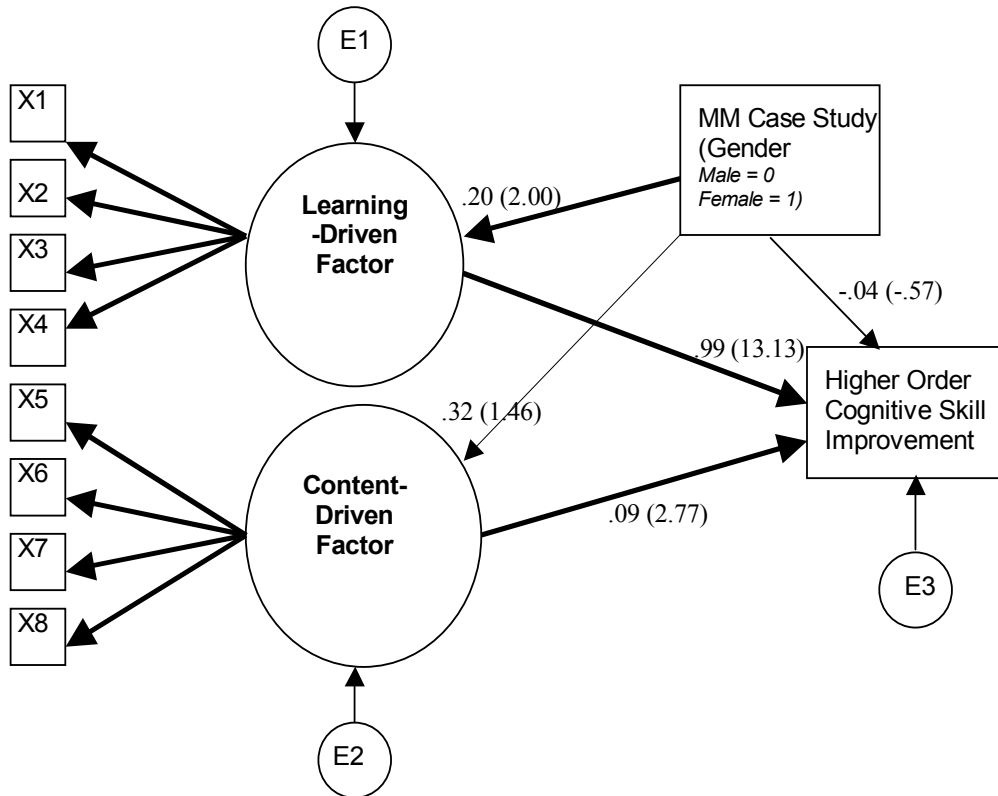
To conclude, this study shows that an indirect relationship between gender and higher order cognitive skills improvement was accounted for by the learning-driven factor as the intervening variable. It found no direct relationship between gender and higher order cognitive skills improvement. Therefore, 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, for both the female and male gender, 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 and DUE# 9950514. 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

References are not provided due to page restrictions. These are available from the authors on request.



Where:

X1 = self reported learning

X2 = learning interest

X3 = learned from others

X4 = challenging

E1, E2 and E3 = Error Terms

X5 = timeliness

X6 = ease of use

X7 = quality

X8 = locatability

→ Significant relationships

→ Non-significant relationships

**Figure 1. Direct and Indirect Relationship between Gender and Higher Order Cognitive Skills Improvement (the t-statistics are in parentheses)**