Identification of Factors That Lead to Perceived Learning Improvements for Female Students

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Abstract—Past research has shown that females have more negative attitudes toward engineering and technology than do males. These negative attitudes may explain the decreasing number of females choosing technical careers. Past studies have shown that a change in learning environments and the methods by which learning takes place might foster a change in this situation. A multimedia case study incorporating a real-world engineering and technical problem faced by a power plant was developed in order to provide a new learning environment for engineering and business students. This research investigates whether the use of this material by female and male students led to differences in perceived higher level cognitive skills and, if so, seeks to identify the factors that cause the difference.

A research model was developed to show the potential relationships between gender and higher level cognitive skill improvement with two intervening variables: the learning-driven factor and the content-driven factor. The learning-driven factor is composed of constructs that show the intrinsic value of the instructional materials to the end user. The learning-driven factor also explains how the multimedia instructional materials were used as a tool to challenge the end user in learning difficult management and engineering topics, in connecting theories and practice, in improving students’ understanding of basic concepts, and in providing the students a platform on which to learn from one another. The content-driven factor is composed of constructs that measure the extrinsic value provided to the end user by the use of multimedia instructional materials. The end user has no control over the design of this factor. This factor constitutes the technical quality of the multimedia instructional material, how easy it is to use and locate information contained on the instructional material, and how the design of the instructional material helped to make it easier and more feasible to complete assigned tasks in a timely manner.

Two questionnaires collected information from 140 students who participated in the experiment (99 men and 41 women). A structural equations model was used to compute the coefficients of the relationship indicated in the research model. An analysis of the results from the model shows that both groups perceived an improvement in the learning-driven factor. Female students valued the learning-driven factor more highly than did their male counterparts, suggesting that it is improvements in the actual learning process triggered by the system that is more important for this group. The results suggest that when designing new learning environments, it is important for the female students to be challenged and have opportunities both to learn by themselves and to learn from others. These results have implications for teaching programs, such as the provision of opportunities for group learning, especially for female students.

Index Terms—Case study, engineering, gender, learning, multimedia, process.

I. INTRODUCTION

Research has shown that females have more negative attitudes toward information technology (IT) than do males [1]–[3]. Other researchers argue that these negative attitudes may affect the interactions of females with computers and explain the decreasing number of females embarking on technical careers [4]. Indeed, women accounted for approximately 12% of all electronics engineering students from 1990 to 1996, but in 1997 and 1998, the percentage rose only to 12.8 and 13.5%, respectively [5]. According to the National Society of Professional Engineers (NSPE), Alexandria, VA, and IBM, Co-Chairs of the National Engineers Week 2001, the engineering profession is facing not only a dearth of engineers in general, but a lack of diversification. Only 9% of engineering positions and 27% of computer science and programming jobs are currently filled by women, and the number of women graduating from college with engineering degrees has evened out in recent years. These numbers underscore the urgency, they say, to encourage women to excel in math and science as early as elementary school and to prepare them for formal engineering courses in college [6].

In investigating how women students are attracted to and retained in engineering fields, there is a need to look at the learning environments in engineering classrooms and whether the gender of the user needs to be taken into consideration. Gefen and Straub [7] argue that women and men differ in their perceptions of technology. The same study suggests that managers and co-workers need to realize that the same mode of communication may be perceived differently by the sexes, suggesting that more favorable communications environments need to be created that take into account not only organizational contextual factors but also the gender of the users. Many studies provide evidence that females and males perceive multimedia information differently [8]–[10]. Gender-specific attitudes might need to be considered when designing learning environments that use some form of information technology [11].

In their careers, students have to deal with complex engineering and technological decisions. Therefore, the following research question was formulated: Does the use of multimedia instructional materials by male and female students lead to perceived differences in the ability to identify, integrate, evaluate, and interrelate concepts in a given problem-solving situation,
thereby impacting their higher-level cognitive skills? If so, do the learning-driven factor and/or the content-driven factor cause the difference?

This paper attempts to answer this question by reporting the results of an experiment. A case study that incorporates a real-world engineering and technical problem faced by a power plant 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, bringing the engineering problem to life for the audience. In addition, an expert system was incorporated in the case study to model the "multicriteria" decision situation and provide an opportunity for performing sensitivity analysis on the recommendations. A research model was developed to show the potential relationships between the variables and the outcome.

Female and male students, from the college of business and the college of engineering, participated in an experiment in which they analyzed the case study and made their recommendations. Two questionnaires measured their perceptions of the improvements achieved on different items. A structural equations model was developed in order to answer the research question, and responses from the female and the male students were compared. The results of the experiment show that men and women perceive improvements in higher level cognitive skills differently based on the intervening variables. This finding leads to a series of recommendations and suggestions for the direction of future research.

II. RESEARCH ON WOMEN’S PARTICIPATION IN IT

This section discusses the past research on women’s participation in information technology in the UK, research on their learning styles, and efforts to improve retention of women in engineering and IT fields. In addition, other research studies on the impact of multimedia technologies on gender are referenced when the results of this study are presented in Sections V and VI.

A. Research in the UK

In the UK, women’s overall participation in higher education has exceeded that of males since 1994 [12]. However, the overall success story disguises disparities across courses, and women continue to be underrepresented in computing and IT [13]–[15]. Although there has been a large expansion in the overall numbers of students studying computing, the percentage of women taking computing/IT courses has fallen. Only 18% of the students entering UK computer science courses in 1996 were women from the UK, and this proportion falls to 11% for the software engineering courses [16]. The decline in interest among women in taking engineering and technology courses is a cross-national phenomenon, with the percentages of women taking IT/computing courses falling in 12 countries, including the USA, between 1985 and 1990 [17].

B. Research on Women’s Learning

After more than two decades of equal opportunity policies, the failure to recruit an adequate number of women in engineering programs points to the resilience of the underlying structuring of disciplines and technologies [18]. The “failure” cannot be with individual women; the same period has seen the success of young women in schools [19]; and women have shown themselves to be willing and capable of breaking through into many previously male-dominated professions, e.g., medicine and law [20]. In the language of the British Women into Science and Engineering (WISE) initiative, women have “wised up,” but when they have done so, they frequently have not chosen IT or engineering-based subjects.

C. Improving Retention of Women in Engineering and IT Fields

Researchers have pointed to the importance and the complexities of improving retention of women in engineering and IT fields [21]–[25]. The computer industry has realized the importance of considering the gender impact when designing learning environments that use multimedia materials, such as PC games for children. In the second half of the 1990s, some steps were taken to develop multimedia-based technologies specifically to improve learning for women. After years of mindful neglect, the computer software industry has finally paid attention to women [26]. In fall 1996, a handful of companies released PC games and multimedia entertainment products aimed specifically at females age 8 and older, equivalent to the mostly male Nintendo aficionados. It was a huge untapped market. Such big companies as Philips Media and Mattel discovered that there is money to be made by giving women something fun to do with computers. Such smaller companies as Girl Games and Her Interactive are now using this business opportunity to help ensure that women stay interested in technology through the use of multimedia technology [26]. If the computer games industry uses multimedia material catered to women specifically, it is an indication that such material can also be helpful in communicating technical and engineering issues to women.

III. RESEARCH MODEL VARIABLES AND QUESTIONS

Given the positive 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. A research model (shown in Fig. 1) was formulated based on past research [27]–[29].

The gender construct (A) in this model was manipulated by a two-dimensional (2-D) variable: female versus male students. Higher order cognitive skills improvement (D) was measured by a set of items that were validated in earlier research studies. The constructs and items corresponding to learning-driven factors (B) and content-driven factors (C) were derived from earlier studies published in the literature.

The obvious research direction is to examine the relationship between A and D (AD only) and come to conclusions about whether female students improve their higher-level cognitive skills compared with male students, given a particular learning environment. Past research [27] indicates that it is important to consider other variables (such as variables B and C) that might...
explain the differences in the value of the variable D. Therefore, several research questions were formulated.

- As shown in the relationship AD in Fig. 1, does the gender of the person directly influence possible differences in perceived higher order cognitive skills?
- If not, do the perceptions of female and male students to the multimedia instructional materials differ? Furthermore, do the learning-driven factors and/or content-driven factors explain possible differences in perceived higher order cognitive skills (such as the relationships AB and BD and/or AC and CD)?

In order to clarify the research model and questions, each factor shown in the model must be defined.

A. Gender (Factor A)

Gender indicated whether the student was female or male. In this study, gender was indicated by a dummy variable (0 indicates male and 1 indicates female).

B. Higher-Order Cognitive Skills (Factor D)

This factor 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 thus make the appropriate decision in a given problem-solving situation [27]. This construct was derived from a study by Higson et al. [27] and includes the following items: identify, integrate, evaluate, confidence, interrelate, connect, make a decision, and solve the problem.

C. Learning-Driven Factor (B)

The 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 learning, self-reported learning, and learning from others measure the end user’s perceived intrinsic achievements as a result of the experiment. Each construct was measured by multiple items, and these items were adopted from past studies [27], [28], [30]. These constructs are now defined.

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

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

D. Content-Driven Factor (C)

The content-driven factor is composed of constructs that measure the extrinsic value provided to the end user through multimedia instructional materials. It includes the constructs of quality, location, ease of use, and timeliness. These constructs were adopted from a past study [30]. These constructs are now defined.

- Quality was used to determine whether the data was sufficiently current 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.

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

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

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

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

IV. RESEARCH METHODOLOGY

The hypotheses were tested by conducting a field experiment in several classes at a major university in the southeastern USA. This section describes the instructional materials, the experimental design, the subjects, the instrument, and the analysis procedures used in this study.

A. Instructional Materials

1) Development of a Case Study to Bring “Multicriteria” Engineering and Technical Decisions to the Classroom: A case study, Crist Power Plant, was developed by working with Gulf Power Company in order to bring a typical real-world engineering and technical issue to the classroom [31]. 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;
TABLE I

<table>
<thead>
<tr>
<th>Construct</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor B: Self Reported</td>
<td>Improved my understanding of basic concepts, learned new</td>
</tr>
<tr>
<td>Learning (3 items)</td>
<td>concepts, learned to identify central management and technical</td>
</tr>
<tr>
<td></td>
<td>issues.(^{ab})</td>
</tr>
<tr>
<td>Factor B: Learning</td>
<td>Discussed technical and managerial issues outside of class, did</td>
</tr>
<tr>
<td>Interest (3 items)</td>
<td>additional reading on technical and managerial issues, did some</td>
</tr>
<tr>
<td></td>
<td>thinking about technical and managerial issues.(^{ab})</td>
</tr>
<tr>
<td>Factor B: Learned from</td>
<td>Learned to value other students’ point of view, learned to inter-</td>
</tr>
<tr>
<td>Others (2 items)</td>
<td>relate important topics and ideas.(^{ab})</td>
</tr>
<tr>
<td>Factor B: Challenging</td>
<td>Brought real life problems successfully to the classroom, challenging,</td>
</tr>
<tr>
<td>learning (4 items)</td>
<td>helpful in learning difficult topics, helpful in transferring theory to</td>
</tr>
<tr>
<td></td>
<td>practice.(^{ab})</td>
</tr>
<tr>
<td>Factor C: Timeliness</td>
<td>Completed tasks on time, case study reports delivered on time.(^{abc})</td>
</tr>
<tr>
<td>(2 items)</td>
<td></td>
</tr>
<tr>
<td>Factor C: Ease of Use</td>
<td>Learned easily, easy to use, had enough training to use the case</td>
</tr>
<tr>
<td>(3 items)</td>
<td>study.(^{bc})</td>
</tr>
<tr>
<td>Factor C: Quality</td>
<td>Was current, up to date, data needed available, useful, appropriate</td>
</tr>
<tr>
<td>(6 items)</td>
<td>level of detail, sufficiently detailed.(^{c})</td>
</tr>
<tr>
<td>Factor C: Location</td>
<td>Was easy to find, easy to locate data, obvious, exact definitions of</td>
</tr>
<tr>
<td>(4 items)</td>
<td>terms were available.(^{c})</td>
</tr>
</tbody>
</table>

\(^{a}[26]; \(^{b}[27]; \(^{c}[29];

b) the importance of developing and prioritizing project criteria in analyzing alternatives;

c) the use of an expert system as an integral part of the decision-making process.

The researchers discussed with the plant manager the maintenance and planning schedules of a turbine generator unit in the Crist Power Plant during January–August 1997. They then visited the plant and observed the actual implementation of the decision that had been reached during January–March 1998. Two videos and a multimedia CD-ROM were created to show the problem and how the solution that was selected was implemented [32]. The problem addressed in this case study can be summarized as follows:

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

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 the analytic hierarchy process [33]. This software assists a decision maker in solving complex problems that involve many criteria and several possible courses of action. It provides the tools needed to construct decision frameworks for both routine and nonroutine problems and to utilize these decision frameworks in ways that include an individual user’s value judgments.

Using this software, Mark identified the goals, alternatives, criteria, and subcriteria involved in making the decision (shown in Fig. 2). After developing the model, the next step is to compare the criteria of cost and risk, then compare the subcriteria against each other, and finally, compare the alternatives under each subcriterion. Mark then 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 subcriteria and uses the principles of alternative hierarchy process to derive overall priorities and rankings for the alternatives. Table III shows the performance graph provided by the Expert Choice model. This graph shows that alternative 4 is preferred, since it has a priority of 23.7%.

After seeing the charts, the plant manager stated:

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 with the other power plants in Southern Company. That would
TABLE II
COSTS OF THE ALTERNATIVES

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Use of the 1980's Stator bars</th>
<th>Install new Stator bars</th>
<th>Block and repair Rotor</th>
<th>Buy Spares 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>-</td>
<td>$300,000</td>
<td>-</td>
<td>$200,000</td>
<td>$1,210,000</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>$850,000</td>
<td>-</td>
<td>$300,000</td>
<td>-</td>
<td>$110,000</td>
<td>$1,410,000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>$550,000</td>
<td>-</td>
<td>-</td>
<td>$633,000</td>
<td>-</td>
<td>$117,000</td>
<td>$1,300,000</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>$850,000</td>
<td>-</td>
<td>$633,000</td>
<td>-</td>
<td>$117,000</td>
<td>$1,600,000</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$1,800,000</td>
<td>$500,000</td>
<td>$2,300,000</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2. An Expert Choice model for Crist power plant.

TABLE III
SENSITIVITY ANALYSIS WHEN RISK HAS 40% AND COST HAS 60% OF THE WEIGHTS.

<table>
<thead>
<tr>
<th>Weighting Provided to each Criteria</th>
<th>Final priorities for Each Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>40% RISK</td>
<td>23.7% for alternative 4</td>
</tr>
<tr>
<td>60% COST</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>

be a highly desirable consequence given the pressures of deregulation of the power industry.

2) Incorporation of Multimedia Elements in the Crist Case Study: A CD-ROM was created in order to show the problem to students [32]. The problems were shown visually using videos of the plant personnel discussing the issues, and then student groups were assigned roles. Videos of the plant manager and plant engineers led the students to the problem. The visual presentation included an actual plant outage planning and implementation process. Photos, animation, and videos were used to cover the concepts of project management, planning, vibration principles, and decision-making. Expert system software, Expert Choice, was made available as part of the CD-ROM, and students were able to load and use this software to analyze the decision model. Videos, audios, photos, and animation augmented the students' ability to grasp the complex engineering materials and made it possible to apply decision-making theories. The students were given the option either to play the video or to read the text version of the case study related to that screen.

The students were provided with a tools section that contained the basic competency materials that they would need to analyze the complex engineering and technical problems involved in the decision-making scenario. 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 involved in this decision-making situation. The students were given the results produced by the Expert Choice software and, in addition, had the opportunity to work on the decision model itself so that they could perform a sensitivity analysis on the problem.

B. Experimental Design

A field experiment was conducted in one engineering and two business classes. The same multimedia version of both case
studies was administered to all the students. The undergraduate business class was a 5-h management class at the sophomore and junior level. The undergraduate engineering class was a 2-h engineering design class at the sophomore and junior level. For both the business and the engineering classes, the students were given access to the CD-ROM in a computer lab.

1) Subjects: A total of 140 students participated in the experiment conducted during the winter and spring 2000 quarters. Of the 140 students, 41 were female and 99 were male. The students were of similar background in terms of age and student status (undergraduate sophomores and juniors). Most of the students had no information systems or engineering related work experience.

2) Instrument: Two questionnaires were designed to elicit responses based on the items defined in Table I. The questions were similar to those used in earlier studies [27], [30], 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 an 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, location, ease of use, learning interest, challenging learning, timeliness, self-reported learning, learned from others and one construct of higher order cognitive skills improvement (shown in Table I).

The students completed the questionnaires and submitted them 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 [34] proposes an alpha of 0.80 and higher, while Tracy [35] suggests a value of 0.70 or higher. Since all the constructs were based on previous studies and since this is an exploratory study, the authors expected the values of Cronbach alphas to be well above 0.7.

3) 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 relationship (with the learning-driven and content-driven factors as the intervening variable) between gender and higher order cognitive skills improvement. The path analysis tool used in this study was 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.

### Table IV: Descriptive Statistics for the Female and Male Students.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Constructs</th>
<th>Mean (s.d.) for Female Students</th>
<th>Mean (s.d.) for Male Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor D</td>
<td>Higher Order Cognitive Skills Improvement</td>
<td>4.00 (.52)</td>
<td>3.70 (.60)</td>
</tr>
<tr>
<td>Learning-Driven Factor (B)</td>
<td>Self Reported Learning</td>
<td>3.80 (.67)</td>
<td>3.61 (.86)</td>
</tr>
<tr>
<td></td>
<td>Learning Interest</td>
<td>3.00 (.85)</td>
<td>3.20 (.82)</td>
</tr>
<tr>
<td></td>
<td>Learned from Others</td>
<td>3.97 (.56)</td>
<td>3.73 (.67)</td>
</tr>
<tr>
<td>Content-Driven Factor (C)</td>
<td>Challenging Learning</td>
<td>4.01 (.58)</td>
<td>3.78 (.65)</td>
</tr>
<tr>
<td></td>
<td>Timeliness</td>
<td>3.87 (.76)</td>
<td>3.67 (.79)</td>
</tr>
<tr>
<td></td>
<td>Ease of Use</td>
<td>3.55 (.76)</td>
<td>3.45 (.69)</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>3.51 (.48)</td>
<td>3.36 (.56)</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>3.64 (.64)</td>
<td>3.52 (.58)</td>
</tr>
</tbody>
</table>

V. RESULTS

The responses to the questionnaires were analyzed first to find out whether the items under each of the constructs that defined the content-driven and learning-driven factors coalesced adequately by computing Cronbach alphas. Then the means and standard deviations of the constructs under each of these factors were computed. Next, the Amos procedure was run to compute the path coefficients and t statistics for the relationships AD, AB, BD, AC, and CD shown in the research model (Fig. 1). The results of these analysis procedures are described in this section.

A. Measuring the Reliability of the Constructs and Their Means and Standard Deviations

The Cronbach alphas were computed for each construct. The alphas were 0.78 for self-reported learning, 0.83 for learning interest, 0.71 for learned from others, 0.81 for challenging learning, 0.78 for timeliness, 0.66 for ease of use, 0.96 for quality, and 0.89 for location. 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.

Statistical processes were used to identify the constructs that compose the learning-driven and content-driven factors. 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 are shown in Table IV.

B. Validating the Research Model and Computing the Coefficients

The Amos program was used to compute the coefficients and t statistics for each of the relationships in the research model. Fig. 3 presents the results of the factor loadings and t statistics used to evaluate the direct and indirect relationships between gender and higher order cognitive skills improvement.

Test of Direct Relationship AD: The direct relationship between gender and higher order cognitive skills improvement
(shown in Fig. 3) is not significant. The path coefficient of −.04 is very low and the t statistic of −0.57 is less than the cutoff value of 2.

Test of Indirect Relationships AB, BD and AC, CD: The indirect relationship between gender and higher order cognitive skills improvement is positive and significant for the learning-driven factor (AB, BD). As shown in Fig. 3, the path coefficient is 0.20, and there is a t statistic of 2.00 between gender (A) and this factor (B). The path coefficient between the learning-driven factor (B) and the higher order cognitive skills improvement (D) of .99 is high, as is the t statistic, 13.13, which is well above the cutoff value of 2.

The indirect relationship through the content-driven factor is not significant. The path coefficient of .32 and t statistic of 1.46 is not significant for the relationship between gender (A) and the content-driven factor (C). However, the relationship CD is significant since the path coefficient is .09, and the t statistic, 2.77, is above 2.

VI. FINDINGS AND IMPLICATIONS

Based on these results, several findings have been identified.

• There was no significant direct relationship between gender and higher order cognitive skills improvement for both groups (AD).
• Both groups perceived an improvement in the learning-driven factor. The students felt that the use of the system improved the learning process itself (AB).
• Female students perceived better higher order skills improvement compared with male students (BD).
• Female students valued learning-driven factors more than content-driven factors compared with male students. The learning-driven factor was more important in the improvement of cognitive skills for females than for males, suggesting that it is improvements in the actual learning process triggered by the system that is more important for this group (AB, BD, and AC, CD).

These findings will be discussed in more detail in the remainder of this section.

A. No Significant Direct Relationship Between Gender and Higher Order Cognitive Skills Improvement (AD)

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 finding agrees with past research on gender and self-efficacy with computer use. Murphy, Coover, and Owen [36] found the highest differences in self-efficacy when computers were used on an advanced level. They found that gender itself did not seem to account for differences between males and females with respect to attitudes toward computers and stated that other factors might play a strong role in this process. The remaining findings in this research study shed more light on the other factors that play a strong role.

Fig. 3. Direct and indirect relationship between gender and higher order cognitive skills improvement. The t statistics are in parentheses. X1: Self-reported learning. X2: Learning interest. X3: Learned from others. X4: Challenging learning. X5: Timeliness. X6: Ease of use. X7: Quality. X8: Location. E1, E2, E3: Error terms. Thick arrow: Significant relationships. Thin arrow: Non-significant relationships.

B. Both Groups Perceived an Improvement in the Learning-Driven Factor (AB)

The second finding is that both groups of students perceived an improvement in the learning-driven factor, with female students reporting a significant increase (a factor load of .20 with a t statistic of 2.00). As shown in Table IV, the means of all constructs under this factor, except learning interest, were above 3.5, showing that both female and male students perceived an improvement in the learning-driven factor. Three constructs under this factor—self-reported learning, learned from others, and challenging learning—were analyzed further, and the findings are as follows.

1) Self-Reported Learning: The mean for self-reported learning was 3.66 for the whole group, indicating that the students perceived an improvement in this construct. Self-reported learning was greater with female students than with male students (3.8 versus 3.61, respectively). In this regard, the female students perceived an improved understanding of basic concepts and new concepts and found that it helped them to identify central management and technical issues from the case study. This discovery confirms the finding from Ehrlich and Reynolds [37], who stated that multimedia instruction provides an opportunity to reach people with different learning styles and different skills levels, while at the same time offering the potential to reduce the learning curve and accelerate the learning process. Some students commented:

"I have learned quite a bit about myself as [a] student while working through the case study. While the case study was quite different, it helped broaden my understanding of MIS concepts in the real world.”

"I learned that business decisions do not always have a certain answer that is considered ‘correct.’ You simply have to weigh the options you have and pick the one you feel best suits your needs. This sort of bothered me due to
the fact that you may think and believe that the answer you have arrived at is correct but then, down the road, see that you were completely wrong.”

“As a problem solver, I have learned that I can do the job given to me. I am now capable of sifting through material and organizing it to form an answer.”

“It has given me confidence in my ability to work on a project in different areas of business and industry, and I learned that I must be able to learn the lingo and be able to work with different professionals.”

“I have learned that decision support systems could be especially beneficial to me in business since I often struggle with making decisions.”

2) **Learned From Others:** The female students perceived that they learned more from others with multimedia instruction than did the male students. In this respect, they reported that they learned from their group members by discussing and interrelating important topics and ideas. The overall average was 3.79, whereas it was 3.97 for female students versus 3.73 for male students. This finding reinforces the past studies showing that multimedia materials increase interaction among students [38], [39]. Some students commented:

“I was able to share my ideas, listen to those of others, and combine them to come up with a solution.”

“The case study gave me hands-on experience with working with other students in order to accomplish a goal in a short period of time. I learned that I work well with other students and that this scenario works well in decision making because it brings more ideas to the table. That [working with others] is very critical in the real world.”

3) **Challenging:** A reason for the improved perception of the female students might be because it challenged their multiple senses and fostered teamwork. The overall average for this construct was 3.84; whereas, it was 4.01 for female students versus 3.78 for male students. Woolf and Hall [40] state that the multimedia approach challenges students to want to learn. DiPasquale and McCabe [41] quote one instructor as saying that multimedia makes “students really sit up and focus on what’s going on.” In our study, some students commented:

“It is kind of challenging to learn all those technical terms; however, the case study challenged me to learn a lot about how the power plant works. To this, I think it is good to have a very broad idea about different technologies.”

“It was all very challenging but figuring it all out is where I really learned the most…”

These findings show that designers of multimedia instructional materials need to include materials that will provide opportunities for students to learn from themselves, to learn from others, and to be challenged. These findings are applicable to both female and male students.

C. **Female Students Perceived Greater Higher Order Skills Improvement Compared With Male Students (AB, BD)**

Female students perceived better higher order skills improvement (4.00 versus 3.70) when they used the multimedia CD-ROM compared with male students. In addition, they reported that the learning-driven factor was a significant reason for this improvement. Comparison of the constructs under this factor shows that the female students perceived higher values than the male students, as shown in Table IV, for most of the constructs (self-reported learning: 3.80 versus 3.61; learned from others: 3.97 versus 3.73; and challenging learning: 4.01 versus 3.78). In this regard, female students perceived that multimedia materials were more successful in bringing real-life problems to the classroom, teaching difficult management and engineering topics, and transferring theory to practice. Some female students commented:

“As a problem solver, I learned that everything must be taken into consideration when making a decision; you cannot leave anything out. As a business student, I learned decision-making skills that I can take with me into the working field. As an MIS professional, I have learned that there are many tools out there that can aid in any decision-making process, such as the Expert Choice software.”

“This is preparing me for the ‘real world,’ and I think that colleges should do more things like this, so you won’t be scared and unprepared when accepting a job.”

“As a problem solver, I have a much better understanding of the logic and thought that must be used to make rational and helpful decisions for companies.”

This result implies that in order to engage female students in engineering disciplines, it might be important to incorporate multimedia instructional technologies so that “multicriteria” engineering and technical problems are brought out live and interactively.

D. **Female Students Valued Learning-Driven Factors More Than Content-Driven Factors Compared With Male Students (AB, BD, and AC, CD)**

Even though the content-driven factor did influence the perceived improvement in higher order cognitive skills (relationship CD), the nonsignificant relationship AC (shown in Fig. 3) indicates that this factor was not responsible for the female students’ perceived higher order cognitive skills improvement. The learning-driven factor was identified as the major intervening variable and, as shown in Fig. 3, both relationships AB and BD are significant.

The responses of female and male students to the content-driven factor were similar (relationships AC and CD). They perceived 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 an appropriate level of detail for both the female and male students. They perceived that it was also equally easy to use and locate information presented and that the time needed to complete a task would be approximately the same for both groups. Based on observational data, both experimental groups completed their tasks within the same time range.

In contrast, the female students perceived a higher level improvement on the constructs of self-reported learning, learning from others, and challenging learning compared with male stu-
dents (relationships AB, BD). 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. This finding questions past research that views the female gender as less attracted to engineering and IT issues than their male counterparts [1–3, 18]. This result might imply that the female students valued the improvement in the actual learning process triggered by the use of the multimedia case studies in the classroom compared with the male students. They were able to learn by themselves when using the CD-ROM, enjoyed the opportunities to work with fellow students, and were challenged in solving the real-world problem.

The following female student comments provide further insight about this finding:

“I have learned about the impact of cost in certain situations, and this material gave a real-life example. I’ve learned that as a student, I could some day be involved in many different industries and make decisions for these industries.”

“This opens me up to the possibility of me being in one similar to that of the Crist case. This also reinforces how important technology is to every industry today.”

“I have learned about expert choice and its features. This could be useful if a company, which will require me to help them make choices, hires me.”

“I learned not only how complex the hardware can be but also how complex the decisions impacting the hardware can be. This is where the Expert Choice software provided a good hands-on experience to learn about making a proper decision.”

“I learned a lot about the power plant along with a better understanding of ethics. I had never known anything about the fundamentals of vibration. After reading the material, I learned that there were numerous tools to detect machine problems.”

“It is kind of challenging to learn all those technical terms; however, the case study challenged me to learn a lot about how the power plant works. To this, I think it is good to have a very broad idea about different technologies.”

“It was all very challenging, but figuring it all out is where I really learned the most.”

VII. CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

This study evaluated the perceptions of female and male students on working with a multimedia case study. The results show that, compared with the male students, female students perceived better opportunities to learn from self, to learn from others, and to be challenged. These opportunities led to higher scores on the perceived higher level cognitive skill development for the female students. One cannot, however, extend such an inference to women who are not students. In addition, this study does not claim that the multimedia approach is better than all other modes of instruction. Further research must be done in these areas before generalizing these results.

Replication of this study with an even larger sample size and with a paper-based mode of instruction as a control experiment would improve validity. In addition, a longitudinal multimethod study that involves a variety of data collection approaches is needed to further confirm that the female students’ higher order cognitive skills were improved with the use of multimedia materials to analyze a complex engineering problem. One method could involve a follow up on how they perform at their respective jobs after they graduate from college.

Most engineering faculty members resort to popular tools such as Powerpoint presentations to present information 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 so that the female students, in particular, develop an interest in solving “multicriteria” engineering and technical decisions effectively. It is critical for these multimedia instructional materials to be designed so that students are challenged and provided with opportunities both for learning by themselves and for learning from others. The results of this study have implications for teaching programs, such as the provision of opportunities for group learning, especially for female students.

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