IMPORTANCE OF LEARNING-DRIVEN CONSTRUCTS ON PERCEIVED SKILL DEVELOPMENT WHEN USING MULTIMEDIA INSTRUCTIONAL MATERIALS

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ABSTRACT

Researchers disagree on the impact of multimedia on perceived skill development. This research investigated whether intervening variables such as task-technology factors might explain the difference in the research findings. An experiment was conducted where thirty-nine students worked on a case study using both paper-based and multimedia-based technologies. An exploratory factor analysis design employing a structural equation model was utilized to analyze the data. The findings from this study suggest a strong indirect relationship between multimedia and perceived skill development with learning-driven constructs (challenging, learning interest, self-reported learning, and learned from others). The study concludes that it is critical to consider these factors in developing multimedia instructional materials.

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INTRODUCTION

Researchers disagree over what impact multimedia has on student performance. Some of the positive findings are from Nielsen, Collier, Barrett, Jonassen, Delany and Gilbert, and Oliver. Nielsen reports that multimedia enables non-linear access to vast amounts of information [1]. Other researchers show that with multimedia, users can explore information in-depth on demand and interact with instructional material on a self-paced mode [2, 3]. Others state that multimedia is attention-capturing or engaging to use and represents a natural form of representation with respect to the workings of the human mind [4, 5]. Oliver and Omari carried out a qualitative research study to investigate the learning behaviors of classroom-based students in a World Wide Web (WWW) learning environment [6]. The study suggested that while print (paper-based) instructional materials provided a sound means to guide and direct students’ use of the WWW learning materials, the actual WWW materials were more suited to supporting interactive learning activities rather than conveying content and information.

Some of the negative findings are reported by Dillon and Gabbard; Orr, Poindexter, and Allen; VarHagen and Zumbo; Clark; and Landauer. Dillon and Gabbard reviewed the findings of thirty-five experimental studies of multimedia use in educational tasks that emphasized quantitative, empirical methods to assess learning outcomes [7]. The findings from this research indicated that the benefits of multimedia in education were limited to learning tasks reliant on repeated manipulation and searching of information. Individual differences in the response of learners to this technology seem to be significant. They report that there is not convincing evidence for increased learning in multimedia environments. Orr, Poindexter, and Allen concluded that using multimedia-based information technology in computer-related courses will not positively impact learning [8]. VarHagen and Zumbo, in a study of computer-assisted instruction, found positive student perceptions but no impact on student performance [9]. Clark had suggested that positive student perceptions and performance in such situations may result as much from the novelty of the information technology environment as from the impact of the technology on the teaching and learning process [10]. Landauer reported that despite numerous published reports on the topic of multimedia use, only nine studies of human performance with this technology met minimally acceptable scientific criteria [11].

Assessment of an experiment at a southeastern university using multimedia technologies showed significant improvement in students’ perceived skill development. In order to reconcile the results of this assessment with current literature, it became essential to identify any intervening variables that might not have been considered in the past research. A literature review identified task-technology fit (TTF) factors as a potential intervening variable. Therefore we created a model and a set of hypotheses in order to analyze whether the TTF factors could explain the difference in the research findings. Constructs were developed from past
literature in order to measure perceived skill development and the intervening variables of TTF. A new experiment was conducted in an undergraduate class where part of the class was provided a multimedia case study on a compact disk (CD-ROM) and the other half was provided a paper-based version of the same case study. Questionnaires were administered to evaluate the perception of the students on developing their skills. The student responses were analyzed to test the hypotheses. These led to a set of findings which might be helpful to researchers and developers of multimedia technologies. The article concludes by discussing future research topics.

DEFINITION OF MULTIMEDIA

Multimedia involves technologies that combine several media of communication such as text, graphics, video, and sound. Some authors have used the term interactive media to include multimedia that encompasses the media types such as text, graphics, animation, audio, images, and video [12]. Simply defined, multimedia is the delivery of information in a computer-based presentation that integrates two or more media [13]. It is, however, not necessary to include all of the above media for the system to be a multimedia system.

MODEL

Past Research Results on Testing of a Multimedia Case Study

A case study was created in order to bring real-world issues to engineering and business classrooms. This written case study was developed by a team of educators from the Colleges of Engineering and Business [14]. Later it was modified to incorporate multimedia technologies such as photos, videos, and on-line references [15]. The multimedia courseware that makes use of videos, photos, and audio to explain the technical details was well appreciated by the students. The technologies were specifically designed to teach difficult engineering concepts, such as the importance of oil whip and oil whirl, in analyzing vibration results of a turbine-generator in a power plant. This case study was designed so that the students could learn concepts of plant maintenance while solving a real-world problem.

The two primary objectives for the case study were as follows:

1. To provide material so that theory, practice, and design are brought together to solve real-world problems.
2. To provide material that could develop higher level cognitive skills of the students.
Successful accomplishment of these objectives would support the conclusion that the case studies utilized were an effective method of instruction. An evaluation team assessed the effectiveness of this case study in engineering classrooms [16]. As part of a full evaluation of the effectiveness of the case-study method of instruction, students \(N = 23\) in a mechanical engineering course—ME 260, Concepts of Engineering Design—were given two separate evaluation forms at the completion of the case study. Two constructs used in the study were “important and valuable” as well as “relevant and useful” [17]. These two constructs had medians of 4.0 on a scale of 1-5, from strongly disagree to strongly agree. This indicated that the students found the case study particularly “important and valuable” as well as “relevant and useful”—important elements in effective learning [17]. The reactions of the students to the various aspects of the Della Steam Plant Case Study were favorable. “Self-reported learning,” “intrinsic learning and motivation,” and “ability to learn from fellow students” (all yielding medians of 4.0) were highly rated by the students. In other words, the Della Steam Plant Case Study appeared to be well received and educationally advantageous to the students. In general, the comments from the students were positive, favorable, and supportive of the case-study method and the Della Steam Plant Case Study in particular.

As part of a full evaluation of the effectiveness of the case study method of instruction, students \(N = 17\) in a class at a predominantly Black university were given the same evaluation forms at the completion of the Della Steam Plant Case Study. This particular sample of students were predominantly seniors (76%) with strong grade point averages (a range from 2.85 to 4.00, with over half above a 3.00) majoring in electrical engineering (94%). They have had little real-life work experience, with only 56 percent having had a job and 37 percent having worked in an internship. In other words, the case-study method of instruction could be of particular benefit to this group, as this method simulates real-life experiences. If students at this university respond to the Della Steam Plant Case Study as favorably as their student counterparts at the major southeastern university, then the effectiveness of this particular case study can be accepted more readily, and it can be concluded that instructor effect or environmental context did not play an important role in the students’ reactions. The evaluation results show that the median ratings, all of which are equal to or exceed 4.0 for each construct, indicated that the students at the predominantly Black university found the Della Steam Plant Case Study to be an effective educational tool. Interestingly, the responses to the items for the construct “learn from fellow students” produced the highest rating of 4.5. “Perceived skill development,” “self-reported learning,” and “intrinsic learning and motivation,” important instructional outcomes of the case study method, all yielded medians of 3.7 or above. In other words, these constructs were highly rated by the students. In general, the Della Steam Plant Case Study appeared to be well received and educationally advantageous to the students at this university. The students enjoyed the activity and they felt that they benefitted from
the activity. Regardless of the environment, context, or instructor, the Della Steam Plant Multimedia Case Study was rated favorably by students as a valuable educational tool.

**Need for a New Research Model**

The strong results shown above are not consistent with the past research results where the evaluation of multimedia case studies had been both positive and negative. Therefore, the study reported in this article was undertaken to identify the factors that led to the strong positive results for the Della Case Study. A major difference between the multimedia courseware used in this study and others is that the material explained is highly technical and the students came from engineering classrooms. Therefore, we hypothesized that the introduction of Task-Technology (TTF) factors as an intervening variable might be an important element in measuring the value of multimedia technologies to perceived skill development.

**Research Model and Hypotheses**

We investigated whether TTF factors make a difference in the student's perceived skill development when using the multimedia-based case study as compared to using a paper-based case study. This therefore led us to a set of research questions:

- Is there a direct relationship between the technology characteristics (paper-based and multimedia-based) and perceived skill development?
- Is there an indirect relationship between the technology characteristics (paper-based and multimedia-based) and perceived skill development with TTF factors accounting for the difference?

The Goodhue and Thompson research model on Task-Technology Fit (TTF) and individual performance was modified in order to create the research model [18]. Their model suggests that task-technology fit, when decomposed into its more detailed components, could be the basis as a strong diagnostic tool to evaluate whether information systems and services in a given organization are meeting user needs.

Figure 1 shows the research model that was created based on the Goodhue and Thompson model. This figure shows a direct relationship between technology characteristics and perceived skill development, as well as an indirect relationship between technology characteristics and perceived skill development with TTF as the intervening variable. The technology characteristics in this model were manipulated by a two-dimensional variable: paper-based versus multimedia-based case study. Perceived Skill Development was used as a surrogate to measure performance impact. The task characteristics were kept constant by repeating the same experiment in two sections of a class. The TTF factors were derived based on past literature. Each of these constructs is defined next.
Technology Characteristics

Technology characteristics could be measured using various dimensions. The characteristics of the system used in our study were captured by a dummy variable (0 indicates use of the paper-based system; 1 indicates use of the multimedia-based system).

Task-Technology Fit

Task-Technology Fit (TTF) is the degree to which a technology assists an individual in performing his or her portfolio of tasks. More specifically, TTF is the correspondence between task requirements, individual abilities, and the functionality of the technology [19]. A literature review showed that the eight constructs of quality, locatability, timeliness, self-reported learning, learning interest, learned from others, challenging, and ease of use would be appropriate in evaluating the factors that comprise the task-technology fit construct.

The constructs for quality, locatability, timeliness, and ease of use were adopted from the Goodhue and Thompson model [18]. The constructs for self-reported learning, learning interest, learned from others, and challenging were adopted.
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from the Kramer et al. [20] and Sankar et al. [21] models. Table 1 lists the items that were used to measure each construct of TTF and the literature from which they were derived. The constructs are defined below.

- **Quality** was used to determine whether the data used was current enough to meet the students’ needs to evaluate the case study. Quality also determined whether it was the right data (maintaining the necessary fields or elements of data) and had the right level of detail.
- **Locatability** was used to refer to the ease of determining what data was available, where the data was available, and the ease of determining what a data element meant, or what was excluded or included in calculating it.
- **Timeliness** was used to determine whether the students’ tasks were completed on time.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality (6 items)</td>
<td>Current, up-to-date, needed data, useful, appropriate level of detail, sufficiently detailed [18].</td>
</tr>
<tr>
<td>Locatability (4 items)</td>
<td>Easy to find, easy to locate, obvious, exact definitions of terms were available [18].</td>
</tr>
<tr>
<td>Timeliness (2 items)</td>
<td>Task completed on time, case study reports delivered on time [18].</td>
</tr>
<tr>
<td>Self-Reported Learning (3 items)</td>
<td>Improved my understanding of basic concepts, learned new concepts, learned to identify central management and technical issues [17].</td>
</tr>
<tr>
<td>Learning Interest (3 items)</td>
<td>Discussed technical and managerial issues outside of class, did additional reading on technical and managerial issues, did some thinking for myself about technical and managerial issues [17].</td>
</tr>
<tr>
<td>Learned from Others (2 items)</td>
<td>Learned to value other students’ point of view, learned to interrelate important topics and ideas [17].</td>
</tr>
<tr>
<td>Challenging (4 items)</td>
<td>Successful at bringing real life problems to the classroom, challenging, helpful in learning difficult topics, helpful in transferring theory to practice [17].</td>
</tr>
<tr>
<td>Ease of Use (3 items)</td>
<td>Easy to learn, easy to use, had enough training to use the case study [18].</td>
</tr>
</tbody>
</table>
**Perceived Skill Development**

Perceived skill development relates to the perception that an individual has acquired an adequate portfolio of skills to perform a given task. Higher perceived skill development implies a mix of improved ability to identify, integrate, evaluate, and interrelate concepts within the case study, and hence make the appropriate decision in a given problem-solving situation. This construct was derived from the Hingorani et al. model [17]. The following five items were used to measure this construct: identify, integrate, evaluate, confident, interrelate.

**Research Hypothesis**

The objective of this study was to compare the effectiveness of two technologies, paper-based versus multimedia-based case studies, on task-technology fit and perceived skill development. The hypotheses are:

**H1:** There is a direct relationship between technology characteristics and perceived skill development.

**H2:** There is an indirect relationship between technology characteristics and perceived skill development, with task-technology fit as the intervening variable.

**RESEARCH METHODOLOGY**

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

**Instructional Materials**

The case study was taken from a written publication entitled “Della Steam Plant” [14]. Della Steam Plant is one of the power plants owned by a major company in the southern part of the United States. Located between a free-flowing river and nearby coal mines, the Della Steam Plant started generating electric power in 1917. The plant has five units in operation. It is an efficiently operated steam power plant producing about 1,000 megawatts of power per day. Sam Towers, plant manager of Della Steam Plant, had no hesitation in shutting down the turbine-generator unit based on the recommendation of Lucy Stone, the manufacturer representative, and Bob Make, the day-shift maintenance engineer.

Lucy Stone ran an overspeed trip test on a turbine-generator unit that was restarted after a two-month preventive maintenance overhaul. The unit began to vibrate heavily and caused the building to shake. An overspeed trip mechanism attached to the turbine-generator tripped causing the unit to coast down to a stop within a few minutes. Many employees were scared and started moving away from the unit. Everyone around the turbine thought that it was going to come apart. Lucy Stone studied the vibration chart produced by the shaft rider probe attached to the turbine generator unit. The chart showed that there was a 17 mil (one thousandths of an inch) vibration level and she felt this was too near the 22 mil clearance between the shaft and the bearing. She recommended to Sam Towers that the unit be torn down and inspected thoroughly. She expected that the retainer rings might have to be replaced. Even though Sam Towers had to make a decision on the same day, he wanted to minimize the possibility of facing such a dilemma in the future. He wanted to deploy appropriate maintenance and information technologies so that the engineers could agree on the final recommendation based on the data.

**Experimental Design**

A field experiment was conducted in MN 405–Information Resource Management, a senior level five-hour undergraduate class. Historically this course was taught through the paper-based lecture mode using a textbook. Since the purpose of the experiment was to compare and contrast multimedia and paper-based materials, a case study was made part of the course structure.

The class was divided into two groups: one that was provided the paper-based case study and the other that was provided the multimedia-based case study. Students were randomly assigned to both groups. The decision as to which group would use either the paper-based or the multimedia-based case study was also random. Both groups were given the material in the same computer lab, but on two different days. Both groups had minimal interaction and were never told, before the experiment, what the other group would be doing during the class time.
Subjects

A total of thirty-nine students participated in the case study conducted during the Spring '99 quarter. All of the thirty-nine students were senior undergraduate students. Eleven were female students. Twenty-four students had a cumulative GPA (grade point average) greater than 2.8 on a 4.0 scale. Most of the students had no information systems or engineering related work experience. Of these, twenty attended the class where the paper-based case study was provided and nineteen attended the class where the multimedia case study was discussed.

Instrument

Three questionnaires were designed to elicit responses related to the items defined in Table 1. The questions were similar to those used in the original study [17], 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-strongly agree to 5-strongly disagree). The questionnaire had items that measured the eight TTF constructs of quality, locatability, ease of use, learning interest, challenging, timeliness, self-reported learning, learned from others, and one construct of perceived skill development (see Table 1).

The students completed the questionnaire and submitted it along with their written comments. Cronbach alpha was computed for each construct to identify whether the items belonged together within a construct. There are several opinions on acceptable levels of Cronbach alphas. For example, Nunnally proposes an alpha of 0.80 and higher [22], while Treacy suggests a value of 0.70 or higher [23]. Since all the constructs were based on previous studies and this is an exploratory study, we expected the values of Cronbach alphas to be above 0.7.

Analysis Procedure

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

The Cronbach alphas were computed for each construct (Table 2). The alphas that measure TTF factors were: 0.81 for quality; 0.72 for locatability; 0.74 for timeliness; 0.77 for ease of use; 0.78 for self-reported learning; 0.73 for learning interest; 0.74 for challenging; and 0.61 for learned from others. The alpha for perceived skill development was 0.73. 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.

Identification of Two Factors that Explain the TTF Constructs

We used an exploratory factor analysis (Figure 2) approach to examine the direct and indirect relationship (with TTF as the intervening variable) between the technology characteristics and perceived skill development. Table 2 shows that there were a possibility of eight factors that might be derived by analyzing the data. The values of the eigenvalues and percentage of variance indicate that it may be possible to factor the constructs to a smaller set of factors that could explain the phenomenon under study. The criterion used here is the percentage of variance criterion. This criterion requires interpretation of the cumulative percentage of variance accounted for by the factor solution. The factors explaining a small percentage of the variance are deemed to be of little practical significance. In the social sciences it is common to consider a satisfactory solution as one that accounts for 60 percent of the total variance.

In this study, the first two factors in Table 3 account for 62.7 percent 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 summarize the TTF constructs.

<table>
<thead>
<tr>
<th>Table 2. Constructs and Their Cronbach Alphas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct</td>
</tr>
<tr>
<td>Quality</td>
</tr>
<tr>
<td>Locatability</td>
</tr>
<tr>
<td>Timeliness</td>
</tr>
<tr>
<td>Self-reported learning</td>
</tr>
<tr>
<td>Learning interest</td>
</tr>
<tr>
<td>Learned from others</td>
</tr>
<tr>
<td>Challenging</td>
</tr>
<tr>
<td>Ease of use</td>
</tr>
</tbody>
</table>
We used an orthogonal VARIMAX factor rotation to see which TTF constructs loaded on the two factors. The rotation converged in three iterations. The results are shown in Table 4. The first factor accounts for 35.7 percent of the total variance and the second factor accounts for 15 percent of the variance. We called the variables learning interest, challenging, self-reported learning, and learned from others that loaded together as “Learning-Driven Factors.” We called
Table 3. Eigenvalues and Percentage of Variance for the Extraction of Component Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalues</th>
<th>% of Variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.277</td>
<td>40.960</td>
<td>40.960</td>
</tr>
<tr>
<td>2</td>
<td>1.741</td>
<td>21.764</td>
<td>62.724</td>
</tr>
<tr>
<td>3</td>
<td>.794</td>
<td>9.924</td>
<td>72.648</td>
</tr>
<tr>
<td>4</td>
<td>.713</td>
<td>8.910</td>
<td>81.557</td>
</tr>
<tr>
<td>5</td>
<td>.633</td>
<td>7.918</td>
<td>89.475</td>
</tr>
<tr>
<td>6</td>
<td>.369</td>
<td>4.616</td>
<td>94.091</td>
</tr>
<tr>
<td>7</td>
<td>.314</td>
<td>3.919</td>
<td>98.010</td>
</tr>
<tr>
<td>8</td>
<td>.159</td>
<td>1.990</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Table 4. Rotated Factor Matrix

<table>
<thead>
<tr>
<th>Loading</th>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning interest</td>
<td>.462</td>
<td>-.050</td>
</tr>
<tr>
<td>Challenging</td>
<td>.749</td>
<td>.324</td>
</tr>
<tr>
<td>Self-reported learning</td>
<td>.834</td>
<td>.147</td>
</tr>
<tr>
<td>Learned from others</td>
<td>.669</td>
<td>.126</td>
</tr>
<tr>
<td>Quality</td>
<td>.010</td>
<td>.609</td>
</tr>
<tr>
<td>Locatability</td>
<td>.171</td>
<td>.805</td>
</tr>
<tr>
<td>Ease of use</td>
<td>.343</td>
<td>.676</td>
</tr>
<tr>
<td>Timeliness</td>
<td>.007</td>
<td>.637</td>
</tr>
</tbody>
</table>

the variables quality, locatability, ease of use, and timeliness that loaded together as "Content-Driven Factors."

Analyzing the data according to the structural model (Table 5) showed that the model had a good fit. Researchers suggest that multiple measures should be used to assess the fit of a model to the observed pattern of correlations in the data [25-27]. Some commonly used measures of model fit, based on results from analysis of the structural model, are summarized in Table 5. The $\chi^2$ divided by the degrees of freedom is used as a measure of acceptable fit [28, 29]. The recommended value ranges from 3, 2, or less [30]. The computed value of 2.08 for this measure is well below most of the suggested cutoff values. Another statistic is root mean square residual (RMSR), which should deviate minimally from zero, with
values less than 0.08 indicating an acceptable fit [33]. Our value of 0.067 for the root mean square residual provides further evidence of good fit.

One important assumption of factor modeling is model determinacy (or identification). An identification problem, in simple terms, is the inability of the proposed model to generate unique estimates. It is based on the principle that we must have a separate and unique equation to estimate each coefficient, reflected in the dictum “You must have more equations than unknowns.” As structural models become complex, there is no guaranteed approach for ensuring that the model is identified [34]. A necessary but not significant condition for identification is when the number of sample moments (information in the data matrix) is greater than the number of parameters being estimated, meaning there is a positive number of degrees of freedom [34]. Based on the results shown in Table 5, our model is identified.

### Test of Hypotheses

Table 6 presents the results of the factor loadings and t-Statistics used to evaluate the direct and indirect relationship between technology characteristics and perceived skill development. Table 7 shows the results of testing the hypotheses.

#### Test of H1

The direct relationship between the technology characteristics and perceived skill development (shown in Table 6) is not significant since the path coefficient of −0.09 is very low and t-statistic (−0.68) is less than the cutoff value.

#### Test of H2

The indirect relationship between technology characteristics and perceived skill development is positive and significant for the learning-driven factor. As shown in Figure 2 and Table 6, the path coefficient is −0.29 and t-statistic of −1.7 between
Table 6. Results of Factor Loadings with t-Statistic in Parentheses

<table>
<thead>
<tr>
<th>Measure</th>
<th>Loadings (t-Statistic)</th>
<th>TTF_Factor 1 Loadings (t-Statistic)</th>
<th>TTF_Factor 2 Loadings (t-Statistic)</th>
<th>Perceived Skill Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>0.41 (1.89)</td>
<td>1.21 (2.78)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locatability</td>
<td>0.54 (2.32)</td>
<td>1.75 (3.44)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use</td>
<td>0.67 (3.50)</td>
<td>1.50 (3.33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning interest</td>
<td>0.71 (2.18)</td>
<td>0.81 (2.55)</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Challenging</td>
<td>1.05 (4.66)</td>
<td>1.035 (4.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timeliness</td>
<td>0.27 (1.99)</td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Self-reported learning</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learned from others</td>
<td>0.94 (4.48)</td>
<td>1.09 (4.43)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Technology characteristics
Learning driven factor: -0.29 (-1.7) -0.25 (-1.95) -0.09 (-0.68)
Technology driven factor: 1.12 (4.53) -0.07 (-0.38)

*A lower value is better since technology characteristics is a dummy variable, and where Multimedia = 1.

Table 7. Results of Testing Hypothesis

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: There is a direct relationship between technology characteristics and perceived skill development.</td>
<td>Not Supported</td>
</tr>
<tr>
<td>H2: There is an indirect relationship between technology characteristics and perceived skill development, with learning-driven factor as the intervening variable.</td>
<td>Supported</td>
</tr>
</tbody>
</table>

technology characteristic and this factor. The path coefficient between learning-driven factor and perceived skill development of 1.12 is high and the t-statistic is 4.533, which is well above the cutoff value. The indirect relationship through the content-driven factors is not significant since the path coefficient is -0.07 and the t-statistic is -0.38, which is below the cutoff value, although technology characteristics and content-driven factors had a significant relationship.

FINDINGS AND IMPLICATIONS

The results have led to identification of factors that might influence the connection between technology characteristics and perceived skill development.
Understanding of the results is essential to researchers and multimedia developers in making the best use of their resources.

**Significant Indirect Relationship between Technology Characteristics and Perceived Skill Development**

*Learning-Driven Constructs Did Influence Perceived Skill Development*

A strong indirect relationship was established between technology characteristics (multimedia-based and paper-based) and perceived skill development. When higher perceived skill development is needed, the learning-driven constructs might explain why multimedia plays a strong role. Various inferences can be drawn from the constructs that comprised this factor: challenging, learning interest, self-reported learning, and learned from others.

Students were more challenged when they used multimedia compared to using paper. In this regard, multimedia was more successful in bringing real life problems to the classroom, teaching difficult management and engineering topics, and transferring theory to practice. A student commented:

> I liked the fact that classroom and business world techniques came together and both were required in order to make a managerial decision.

A major advantage of multimedia use is that it challenges the student’s multiple senses. Woolf and Hall believe that the multimedia approach challenges students to want to learn [35]. DiPasquale and McCabe quote one instructor as saying that multimedia makes “students really sit up and focus on what’s going on” [36].

The students’ learning interest was enhanced more with multimedia than paper. The information presented via multimedia drew students’ interest during and after the experimental class sessions. Some students commented:

> The CD-ROM interface sparked my interest in the case greatly.

> This is more interesting than sitting in class.

> I found the case study to be very enjoyable and a good learning experience.

This finding agrees with the Jonassen study which states that multimedia is attention-capturing or engaging to use [4]. Another important fact to do with enhancing learning interest is that the students discussed technical and managerial issues outside of class after the case study sessions. One of the students wrote:

My group found one Web site that allowed us to e-mail questions to a company that is knowledgeable about turbine generators. Two days after the case study had concluded, I received a response to our questions from that company. Their response included several Web sites which we had not looked at in class that they thought might be helpful. I went and looked at the Web
sites, which allowed me to learn even more about the turbine generators, and I also forwarded the response to my group members.

Self-reported learning was greater with multimedia than with paper. In this regard, multimedia improved the students’ understanding of basic concepts, they learned new concepts, and also learned to identify central management and technical issues from the case study. Ehrlich and Reynolds state 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 [37].

The students responded that they learned from others more with multimedia than with paper. In this respect the students learned from their group members by discussing and interrelating important topics and ideas. Various studies in multimedia show evidence that students benefit from each other when they use multimedia technologies in the classroom [38, 39].

Content-Driven Constructs Did Not Influence Perceived Skill Development

The results show that the content-driven constructs were not responsible for the students reporting improved perceived skill development. Compared to the learning-driven factors, the content-driven factors contributed less to the perceived skill development. If this result is true for a larger sample, it might imply that paper-based information might be equally effective as multimedia to communicate content. For example, in retrieving a phone number people may not differentiate between a phone book and a Web site. Similarly, a blueprint might have the same attractiveness as a sketch on the computer.

For instance, the quality of information about power generation (as used in the experiment for this study) was both current, up-to-date, useful, sufficiently detailed, and had the appropriate level of detail on both multimedia and paper. It is also equally easy to use and locate information presented on both paper and multimedia, and the time to complete a task will be approximately the same for both paper and multimedia. Based on observation data, both experimental groups completed their tasks within the same time range. Therefore, multimedia technologies that duplicate paper-based information without paying attention to learning-driven factors might not be effective.

No Significant Relationship between Technology Characteristics and Perceived Skill Development

The insignificant direct relationship between technology characteristics and perceived skill development shows that it is not the multimedia in itself that accounts for the higher perceived skill development. In this regard, our study agrees with the findings of those researchers who propound that multimedia in
agrees with the findings of those researchers who propound that multimedia in itself does not improve perceived skill development [40, 41]. This might explain why many researchers don’t perceive improvement in perceived skill development when multimedia technologies are provided to people.

CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

This study evaluates the effectiveness of two technology characteristics—multimedia and paper-based—in perceived skill development by a group of students. The research shows that the technology characteristics had a strong influence on learning-driven constructs which in turn led to improved perception of skill development. The dependent variable, perceived skill development, used in this study was based on an experiment performed in learning engineering and managerial issues. Based on these findings, one cannot, however, extend such an inference to learning in other disciplines such as literature and history. Further research must be done in this area before generalizing these results.

The multimedia technology characteristics could also be varied to see if different multimedia combinations could make a difference. For instance, the impact of sound and video versus sound and animations could be experimented. Such a research could find out what levels or combinations of multimedia elements may be used to improve perceived skills development.

Replication of this study with a 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 students’ perceived skill development was improved with multimedia. 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 multimedia and perceived skill development was accounted for by the learning-driven constructs as the intervening variable. It found no direct relationship between multimedia technologies and perceived skill development. Therefore, when higher perceived skill development is needed, the choice of multimedia needs to ensure that the learning-driven constructs are included. It is critical for the multimedia technologies to be designed so that they are challenging, produce learning interest, provide self-reported learning, and provide opportunities to learn from others.

REFERENCES


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