The evaluation of alternate learning systems in an industrial engineering course: Asynchronous, synchronous and classroom

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Abstract

Web-based asynchronous learning systems have revolutionized the learning environment. Rapid advances in computer technology, the internet and transmission technology have created new opportunities for delivering instruction. It is anticipated that these technologies will dramatically change the way instruction will be imparted throughout the educational system. One example is asynchronous learning wherein instruction can be delivered at any place at any time on demand. If we are to use this new mode of delivering and receiving instruction, we need to fully understand its advantages and limitations to existing forms of delivering instruction. In response to this need, this paper describes a study conducted to evaluate the usefulness of delivering instruction asynchronously. The study compared three forms of instruction: classroom, synchronous and asynchronous using student subjects from an industrial engineering course. Even though the results of this study are specific to the industrial engineering course considered, the results could throw new light into the usefulness of the Internet and asynchronous learning in other learning environments.

Relevance to industry

This paper evaluates the usefulness of advanced learning systems in delivering instructions in an academic environment for a specific industrial engineering course. The results of this study could be further expanded to develop distance-learning programs.

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1. Introduction

Traditionally, learning and teaching have been built around the classroom environment with an instructor, using tools like a chalkboard and print material such as books, teaching students who meet at the same place and at the same time, that is synchronously. However, as computer technology has become more accessible and cost-effective, various attempts have been made to integrate it into educational environments. The invention of the internet and, more importantly, of the World Wide Web (WWW), a wide-area hypermedia information retrieval project begun in 1989 by Tim Berners-Lee at the CERN European Laboratory for particle physics (Berners-Lee, 1994), has contributed to this new age of electronic education, offering a wide range of options for communication and the exchange of information. By merging the techniques of information retrieval and hypertext to make an easy-to-use and powerful global information system, it offers millions of pages of information, forming a system of worldwide references.

The statistics about the Web and its users are nothing short of overwhelming. In addition to allowing immediate access to the latest version of a document (Ibrahim and Franklin, 1995), the WWW also allows students great access that is more rapid to broader arrays of more up-to-date information than a traditional university library; affords them more input in their learning process, making education more pro-active; and allows a more individual approach to assessment and learning than is traditionally possible (Sloane, 1997). The implications of such changes are revolutionary, affecting the quality of instruction, its content and its presentation, to name a few. Among the changes is the fact that a student or a group of students may never have to set foot on campus; rather, they can fulfill all the course requirements using the computer and the WWW, never meeting synchronously to listen to the instructor teaching the courses. In addition to facilitating asynchronous learning, it should be noted that the Web can also be used to support synchronous courses or meeting.

Thus, internet technology, and in this case the WWW system, has the potential to create a distance education environment which can exist beyond the traditional boundaries of a particular location to a broad range of students, involving them in highly interactive participation. Today, a student taking an on-campus course may never sit in a classroom; distance students may take a course concurrently with on-campus students, and course instructors may find themselves conducting office hours via electronic means.

As Evans and Murray (1996) found, these asynchronous (different place, different time) distance courses could be successful, with students interacting through an electronic network such as e-mail. These Asynchronous Learning Networks (ALNs), defined as networks for anytime-anywhere learning, combine self-study with substantial, rapid asynchronous interactivity with others. In an ALN environment learners use computers and communications technology to work with remote learning resources, including coaches and other learners, without having to be online at the same time, with the most common ALN communication tool being the World Wide Web. As the empirical study conducted by Boaz and Nath (1997) found, using e-mail, the Web and bulletin boards as tools in ALNs achieved the educational goals of completing homework quickly, improving class performance, increasing productivity in class, enhancing learning and increasing the communication with instructor and peers in an environment appreciated by the students.

To supplement academic performance and increase the power of ALNs, specialists have experimented with various presentation styles and multimedia components, making sure such educational environments are in accordance with new theories of communication systems; consistent with instructive philosophy and styles of teaching; convenient, accessible and relevant to the students; and finally, well-organized and well-presented (Barreau et al., 1994). However, it should be noted that, even though asynchronous learning has been part of the educational lexicon for many years in the form of “individual study,” it is the mode of technology that has revolutionized the teaching methods.
Every new technology has its problems, and ALNs are no exceptions. The transition from face-to-face classroom instruction to ALN instruction can be tricky as both Harasim et al. (1995) and Ory and Bullock (1997) found, especially because students may find the physical non-availability of the instructor and their peers to be a major cause of concern. It is clear that instructional system designers and human factors professionals focusing on training/learning will need guidance on the use of ALNs and, more specifically, on knowing which technology is the best under certain environments to avoid its capricious and arbitrary use. Him et al. (1999) investigated the use of ALNs, developing a methodology to support classroom instruction using alternate delivery systems in addition to investigating various technologies to compliment ALNs. They conducted a study in which the information presented to a class was broken into modules with the technology being used classified as either low- or high-level. Low-level consisted of digital media including the use of e-mail, graphics, text and audio while high-level incorporated the most current technology available, including not only e-mail, text and audio but also animation, video, synchronization of videos and animation, chatrooms, and bulletin boards. In addition, their study developed a methodology for the use of ALNs to supplement traditional classroom instruction. However, it did not take into account the various alternatives in delivering instruction—classroom, asynchronous or synchronous. In response to this need, this current study extended their work by evaluating the effectiveness of alternate delivery systems to promote learning in a specific industrial engineering course, Production Planning and Control.

The specific objectives of this research are:

- to compare the asynchronous, synchronous, and the traditional classroom delivery system using performance, system process and usability measures, and
- to test the effectiveness of these delivery systems for procedural-based tasks using the Forecasting and Aggregate Planning modules of the Production Planning and Control course.

Even though more specific to the course considered, the findings of this study could enable us to prescribe which technology and learning environment is the most effective, an important result since the implications of integrating state-of-the-art technology into education are wide-ranging, affecting the quality of instruction, the public’s access to higher education, and the control consumers have over their own education.

2. Methodology

2.1. Subjects

Twenty-four students, 12 undergraduate and 12 graduate, were drawn from classes in the Industrial Engineering Department at Clemson University. All were between the ages of 18–24 and were compensated for their participation. Subjects were randomly assigned to one of the following three groups, with each having four graduate and four undergraduate students:

(1) **Asynchronous group**: The asynchronous group received a brief introduction to the task to be performed and instructions in the use of the technology delivered asynchronously, that is, imparted at a different place and at a different time for the different members of the group.

(2) **Synchronous group**: The synchronous group received a brief introduction to the task to be performed and instructions in the use of the technology synchronously, that is, imparted at the same place and at the same time to all members.

(3) **Control group**: The control group received instruction in the traditional classroom environment. Furthermore, in an attempt to obtain a homogeneous population and reduce potential subject bias, subjects were chosen with similar levels of computer familiarity and with comparable Grade Point Average (GPA).

2.2. Learning modules

The learning modules used for this study were developed for the Forecasting and Aggregate Planning modules of the Production Planning and Control course.
Planning units for a course entitled Production Planning and Control. Even though it is an introductory course that is taught mainly for undergraduates, graduate students without background in this topic are required to take it. The Forecasting Module consisted of the forecasting accuracy measurements with the following parameters: (a) Mean Forecast Error (M); (b) Mean Absolute Deviation (MAD); (c) Mean Absolute Percent Error (MAP); (d) Sample Error Variance (V); (e) Auto Correlation at Lag k [AC(k)]. The Aggregate Planning Module consisted of comparing two production plans, then choosing the one with the higher expected profit.

2.3. Test equipment

All three groups received instructions using the appropriate equipment. The control group received instructions on the learning modules in a traditional classroom environment using a chalkboard and other materials such as notes. The asynchronous and synchronous groups accessed the same learning modules using computers located in the Industrial Engineering Department at Clemson University. The test equipment for both of these groups consisted of Pentium III computers with 500 MHz CPU clock speed and 128 MB RAM. These computers were connected using a T1 LAN configuration, and all had Internet Explorer 4.0 or Netscape Communicator 4.0 browsers. Real Audio G2 was pre-installed in all of the computers, as suggested by Him et al. (1999) who concluded that the technology for the asynchronous and synchronous groups needed to include Real Audio in addition to the text for the Forecasting Module and Microsoft Windows Media player for the Aggregate Planning Module.

2.4. Experimental design

This study used a two-factor, or Group × Task, design. The group factor—asynchronous, synchronous or traditional instruction—was the between subjects factor and the task was the within subjects factor with 8 subjects tested within each group for a total of 24 subjects.

2.5. Procedure

Initially, all subjects signed a consent form and were given a brief demographic questionnaire. They were then randomly assigned to one of the three groups and received instructions in both Task A, Forecasting and Task B, Aggregate Planning. The teaching content remained constant for all three groups for both learning modules. After receiving instruction, the subjects were given a quiz over each of the tasks to test their knowledge of the material. Each subject then filled out a brief usability questionnaire designed by Him et al. (1999) to evaluate each module, corresponding to the group to which the subject was assigned. A comprehensive final examination was then given to all students to test their knowledge of the material of both learning modules.

3. Results

Statistical analyses were performed on the data obtained from the performance measures, process measures, and usability measures. Performance measures included subject performance on both the quizzes and the final examination, whereas process measures included the number of times the module was accessed and the amount of time spent on each, based on the average for all subjects.

3.1. Performance measures

Analysis of variance (ANOVA) was performed on the two quiz scores, one final examination test score, and the sum of the two for all 24 subjects. The results for each of the performance measures are shown below.

3.1.1. Test scores on quizzes

Mean scores on Quizzes 1 and 2 were analyzed using a 3 (Groups) × 2 (Task) factorial design. Neither the main effects (group and task) nor the interaction was found to be significant as shown in Table 1. ANOVA conducted on individual quiz scores using 3 (Groups) × 1 (Task) design did not
show any significant group effect as shown in Table 2.

3.1.2. Test scores on the final examination

Analysis on final examination scores using 3 (Groups) × 1 (Task) factorial design did not find the main effect of group to be significant as can be seen in Table 2.

3.1.3. Total and final test scores

The total scores for each student were calculated as the sum of the scores on the quizzes and the final exam. Again, the analysis using 3 (Groups) × 1 (Task) factorial design did not show any significance for the main effect of group as shown in Table 2.

3.2. Process measures

ANOVA was performed on the time spent viewing the modules and the number of times each module was accessed. The results for each of the process measures are shown below.

3.2.1. Time spent viewing the modules

The data on the time spent by all three groups viewing the modules is shown in Table 3. The data were analyzed using a 3 (Groups) × 2 (Tasks) factorial design. The interaction effect of Group × Task was found to be significant \( (F(2,21)=8.10, p<0.0025) \) as seen in Table 4, as was the main effect of Group \( (F(2,21)=3.59, p<0.0455) \) and Task \( (F(2,21)=54.62, p<0.0001) \).

As seen in Table 5, the results from Fisher’s Least Significance Difference (LSD) Test separating the six interaction means showed that the amount of time spent was not significantly different for the synchronous and asynchronous groups for the Forecasting Module and for the classroom and asynchronous groups for the Aggregate Planning Module.

3.2.2. Number of times the modules were accessed

The data was analyzed using a 3 (Groups) × 2 (Tasks) factorial design. The interaction effect of Group × Task \( (F(2,21)=21.00, p<0.0001) \) was found to be significant as was the main effect of Group \( (F(2,21)=22.40, p<0.0001) \) and Task \( (F(2,21)=21.00, p<0.0002) \), which is shown in Table 4. The presence of interaction indicates that
depending on the group and the task involved, subjects accessed the learning modules variable number of time. Moreover, the results from Fisher’s LSD test seen in Table 5 showed that no significant difference between the classroom and synchronous groups for each module. Also, these groups did not show any difference between the Aggregate Planning and Forecasting modules.

3.3. Usability measures

Subjects’ answers on the usability questionnaire were analyzed using Cronbach’s Analysis as shown below.

3.3.1. Cronbach’s analysis

Subjects in all three groups responded to 10 questions on the usability of the appropriate system. Their responses were recorded using a five-point Likert scale, with one being very strongly disagree and five being very strongly agree. The questions were organized into the following four categories: (1) Content, (2) Usefulness, (3) Organization, and (4) Learning. The questions, along with the mean scores and standard deviations for each group, are illustrated in Tables 6–8.

A Cronbach’s Coefficient Alpha (Cronbach, 1951) was calculated for the three groups to ensure that it was appropriate to place each question in a particular category. The Alpha Coefficient can be expressed mathematically as follows:

$$\text{Alpha} = \left[ \frac{k}{k-1} \right] \left[ 1 - \frac{\sum V_i}{V_t} \right],$$

where $k$ is the number of questions combined, $V_t$ is the variance of the participants’ total scores, and $V_i$ is the sum of the variances of the responses for each individual question.

To ensure that the questions would yield interpretable results about usability, the Cronbach’s Coefficient Alpha should be greater than 0.5 and less than or equal to 1.0 (Cronbach, 1951). Since the coefficients for all the groups were within the prescribed limits, it was found appropriate to place the questions into their respective categories.

### Table 4

<table>
<thead>
<tr>
<th>Source</th>
<th>F value</th>
<th>Amount of time (min)</th>
<th>Number of times</th>
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</thead>
<tbody>
<tr>
<td>Group</td>
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<td>22.40*</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>54.62</td>
<td>21.00*</td>
<td></td>
</tr>
<tr>
<td>Group × Task</td>
<td>8.10</td>
<td>21.00*</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at 0.05.

### Table 5

<table>
<thead>
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<th>Comparison</th>
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<th>LSD</th>
<th>Significantly different</th>
</tr>
</thead>
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<td>9.89</td>
<td>Yes</td>
</tr>
<tr>
<td>$\mu_{df} - \mu_{sap}$</td>
<td>11.75</td>
<td>9.89</td>
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<td>9.89</td>
<td>Yes</td>
</tr>
<tr>
<td>$\mu_{df} - \mu_{df}$</td>
<td>14.00</td>
<td>9.89</td>
<td>Yes</td>
</tr>
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<td>$\mu_{df} - \mu_{df}$</td>
<td>14.00</td>
<td>9.89</td>
<td>Yes</td>
</tr>
<tr>
<td>$\mu_{df} - \mu_{df}$</td>
<td>6.42</td>
<td>9.89</td>
<td>No</td>
</tr>
</tbody>
</table>

$\mu_{df}$ Mean amount of time for the classroom group, Forecasting Module; $\mu_{df}$ Mean amount of time for the synchronous group, Forecasting Module; $\mu_{df}$ Mean amount of time for the asynchronous group, Forecasting Module; $\mu_{df}$ Mean amount of time for the classroom group, Aggregate Planning Module; $\mu_{df}$ Mean amount of time for the synchronous group, Aggregate Planning Module; $\mu_{df}$ Mean amount of time for the asynchronous group, Aggregate Planning Module; $\mu_{df}$ Least significant difference.
For the four categories, the results for each group are shown in Table 9. For each usability category, the data were analyzed using a 3 (Groups) × 1 (Category) factorial design in addition to ANOVA being conducted.

3.3.2. Content

The results from ANOVA show that the main effect of group was not significant. However, the main effect of task \( (F(1, 21) = 9.33, \ p < 0.006) \) was reported to be significant, as shown in Table 10. The mean score of responses in the content category was higher for the Forecasting Module than for the Aggregate Planning Module.

3.3.3. Usefulness

The main effects of both group \( (F(2, 21) = 8.64, \ p < 0.0018) \) and Task \( (F(1, 21) = 24.95, \ p < 0.0001) \) were found to be significant, which can be seen in Table 10. As seen in Table 11, Fisher’s LSD Test for the mean responses in the usefulness category for the different groups showed that the responses between the classroom and synchronous groups and the synchronous and asynchronous groups were not significantly different.

3.3.4. Organization

Table 10 shows that the main effect of group was not found to be significant. However, the main effect of task \( (F(1, 21) = 14.78, \ p < 0.009) \) was significant. The mean scores of responses in the organization category were higher for the Forecasting Module than the Aggregate Planning Module.

3.3.5. Learning

The main effect of both group \( (F(2, 21) = 3.68, \ p < 0.042) \) and task \( (F(1, 21) = 8.04, \ p < 0.0099) \) was found to be significant as shown in Table 10. Fisher’s LSD Test for the mean responses in the learning category for both the classroom and asynchronous groups, seen in Table 12, did not show any significant difference.

4. Discussion

The most salient finding of this study is supported by the performance measures. Analysis of the two quizzes, the final exam and the total scores did not reveal any significant differences across groups, task or the interaction between
groups and tasks, indicating that performance was not sensitive to the type of delivery system. This result is supported by Jamison et al. (1974), who reported that when used as a replacement at the college level, Computer Aided Instruction (CAI) was almost as effective as the traditional means of
In addition, the total scores for the asynchronous group were the highest of the three. Kulik et al. (1980), reported similar increased achievements when computers were used rather than the traditional means of instruction, and Evans and Murray (1998) found that the synchronous meetings of the class body were not a necessary component to the successful execution of an asynchronous distance course. This research, thus, supports implementing Asynchronous Learning Networks (ALNs) using computers since the asynchronous group performed as well as, if not better, than the subjects in a well-designed traditional classroom. While data from the performance measures for the asynchronous group supports Sloane’s (1997) findings that the internet allows a more individualized approach to learning than traditional means, this study also concurs with his position that a well-directed approach combining the World Wide Web and the classroom environment might prove to be more beneficial than just using either delivery system in isolation.

For the process measures, the amount of time spent on each module and the number of times subjects viewed the modules, analysis of the data for the former shows that there was a significant interaction effect between groups and tasks, indicating that depending on the group and the task involved, subjects spent variable amounts of time on learning. In addition, the mean time spent on the Aggregate Planning Module was higher in each group than that for the Forecasting Module, with the LSD Test indicating a significant increase in the amount of time the subjects viewed the

Table 9
Cronbach’s Analysis for the classroom, synchronous, and asynchronous groups

<table>
<thead>
<tr>
<th>Category</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom group, forecasting module</td>
<td>0.88</td>
</tr>
<tr>
<td>Classroom group, aggregate planning module</td>
<td>0.89</td>
</tr>
<tr>
<td>Synchronous and asynchronous groups, forecasting module</td>
<td>0.66</td>
</tr>
<tr>
<td>Synchronous and asynchronous groups, aggregate planning module</td>
<td>0.63</td>
</tr>
<tr>
<td>Content</td>
<td>0.88</td>
</tr>
<tr>
<td>Usefulness</td>
<td>0.62</td>
</tr>
<tr>
<td>Learning</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Table 10
ANOVA for each category of the usability questionnaire

<table>
<thead>
<tr>
<th>Source</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Content</td>
</tr>
<tr>
<td>Group</td>
<td>1.22</td>
</tr>
<tr>
<td>Task</td>
<td>9.33*</td>
</tr>
<tr>
<td>Group × Task</td>
<td>1.97</td>
</tr>
</tbody>
</table>

*Significant at 0.05.

Table 11
Fisher’s LSD Test for the usefulness category in the usability questionnaire

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Difference</th>
<th>LSD</th>
<th>Significantly different</th>
</tr>
</thead>
<tbody>
<tr>
<td>μc - μs</td>
<td>0.17</td>
<td>0.428</td>
<td>No</td>
</tr>
<tr>
<td>μc - μa</td>
<td>0.43</td>
<td>0.428</td>
<td>Yes</td>
</tr>
<tr>
<td>μs - μa</td>
<td>0.26</td>
<td>0.428</td>
<td>No</td>
</tr>
</tbody>
</table>

μc Mean score of the classroom group; μs Mean score of the synchronous group; μa Mean score of the asynchronous group; LSD Least significant difference.

Table 12
Fisher’s LSD Test for the learning category in the usability questionnaire

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Difference</th>
<th>LSD</th>
<th>Significantly different</th>
</tr>
</thead>
<tbody>
<tr>
<td>μc - μs</td>
<td>0.95</td>
<td>0.55</td>
<td>Yes</td>
</tr>
<tr>
<td>μc - μa</td>
<td>0.21</td>
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<td>No</td>
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<tr>
<td>μs - μa</td>
<td>0.74</td>
<td>0.55</td>
<td>Yes</td>
</tr>
</tbody>
</table>

μc Mean score of the classroom group; μs Mean score of the synchronous group; μa Mean score of the asynchronous group; LSD Least significant difference.
Aggregate Planning Module irrespective of the type of delivery system. The asynchronous group reported the highest amount of time spent on this module, 56.42 min, a result that could be explained by the fact that since this group met at a different place and at a different time with no help from peers or an instructor, the subjects had to rely only on the system. The increased amount of time spent on this module also might indicate a more complex task than the Forecasting Module, one with more involved procedural steps. In addition, many of the concepts needed for the Forecasting Module might have been covered in related courses, the impact of prior knowledge thus carrying over to a current task. This carry-over effect was apparently not the case with the Aggregate Planning Module.

The data concerning the number of times the subjects viewed the modules indicated a similar interaction between groups and tasks. The number of times the module was accessed by the asynchronous group was more for the Aggregate Planning Module than the Forecasting Module. Even though the classroom and synchronous groups viewed each module only once, similar trends might have been reported if these groups had met more for each module. The LSD Test again pointed to the fact that a significant difference existed with the Aggregate Planning Module, indicating that this module might have been of higher difficulty than the Forecasting Module, thus perhaps accounting for the increased number of times the subjects viewed it.

The results indicated by the performance and process measures are supported by the analysis of the four categories of questions on the usability questionnaire. In the content category, a significant effect of task was reported: mean ratings for the Forecasting Module were higher than those for the Aggregate Planning Module. Also, the classroom group reported the highest ratings in the content for the Forecasting Module. The simplicity of the task in this module might be an explanation for these higher ratings.

In the usefulness category, there was a significant effect of task as well as group, with the LSD Test indicating a significant difference in the ratings between the classroom and asynchronous groups. The mean ratings for the Forecasting Module were higher than those for the Aggregate Planning Module for all groups. The synchronous group rated the usefulness category higher than the asynchronous group, although both used the same interface and technologies; there are three tentative reasons for this result. One, possibly because the synchronous group had only one interaction per module with the system, the subjects could not sufficiently gauge its usefulness, thereby yielding increased ratings. Secondly, the asynchronous group had no interaction with peers. This feeling of isolation might have discouraged subjects in the asynchronous group, perhaps explaining their lower ratings in this category. Finally, since the hardware, browser settings and connection speeds vary from place to place, the subjects in the asynchronous group might have experienced difficulty with the interface when they accessed the modules from different places.

The main effect of task was significant for the organization category. The ratings of all the three groups were higher for the Forecasting Module than for the Aggregate Planning Module. This might be due to the fact that the Forecasting Module was shorter and less difficult than the Aggregate Planning Module, which had more involved procedural tasks, giving its content a more organized “feel.”

Task as well as group had a significant effect on the learning category of the usability questionnaire. The LSD Test indicated a significant difference in the ratings between the classroom and synchronous groups and between the synchronous and asynchronous groups. The mean ratings for the Forecasting Module were higher than those for the Aggregate Planning Module, irrespective of group. Similar to the usefulness category, the synchronous group rated the learning category higher than the asynchronous group while the classroom group gave the highest ratings in this category. The physical availability of an instructor, which perhaps led to a psychological feeling of learning in its traditional sense, might be a reason for this result.
5. Conclusions

Most importantly, this research concurs with Him’s (2000) earlier findings: performance measures are not sensitive to the medium of delivery system, indicating that instructional system designers and human factors professionals should continue developing and integrating different learning environments to facilitate student learning styles and situations. In addition, this study offers several results which, while not statistically significant, may also have an impact: (a) the unlimited access of the modules for the asynchronous group had a positive effect on performance measures leading to the highest scores on the forecasting quiz and the final exam and ultimately, the total score, (b) analysis of the process data using the traditional measures of speed and accuracy found that these measures significantly affected the task. Thus, for more involved tasks, unlimited access in terms of amount of time spent and number of times the task is used as a training tool might result in better performance. Although the results of this study are specific to the course considered, they could have important implications for other learning environments.

While this study is just the first step, its results indicate that further research is merited. The areas listed below are ones suggested as being among the most promising:

- An investigation to see if the same technology used consistently for both the synchronous and asynchronous groups will yield different results on the performance, process, and usability measures.
- An investigation to see if varying the difficulty of the task affects the subjects’ preference for the technology used in training.
- An investigation into the effect of using adaptive systems in which participants are given mock quizzes that are not graded during a training period.
- An investigation of the effect of task factors on process and performance measures by combining knowledge and procedural-based tasks in an entire course and comparing classroom and synchronous groups.
- An evaluation of the effects of subject factors by studying students with diverse computer backgrounds.

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