Engineering Education and the Internet: A Study of the Effectiveness of Web Formats on Student Learning

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Abstract

There is an explosion of interest in internet classes at all levels of engineering education. The potential and advantages of the internet as an educational delivery mode are huge. The web provides learners with a wealth of resource materials at their fingertips, is available to students at times and locations convenient to the learner, and allows students access to experts across the globe. To maximize the use of this delivery however, the development of teaching materials must be based on a strong foundation of educational research, grounded in appropriate learning theory. To date, the use of web-based learning has out-paced quantitative research on what this media can teach and what type of student can benefit from it. There is a wide variety of ways to present material on the web and little research to guide educators on the optimum format for a given audience.

Constructivist learning theory recognizes that learners are active participants in acquiring their knowledge. A web course that allows the student the freedom to dictate pace, sequence and use of resources would be an example of a constructivist approach. The objectivist approach assumes that there is a structure to knowledge independent of the individual learner, reducing the learner to a passive role. A web textbook format would be an objectivist approach. A study of 145 engineering and science students was conducted to determine the relationship between the format of the web material and learning. Other characteristics that were measured were gender, age, verbal ability, self-regulation, and attitudes towards computers. Results indicate that there were no significant differences in student learning between the two web formats. No significant differences were found with respect to self-regulation, attitudes, gender, or verbal ability.

1. Education and the Internet

Developments in media and communication technologies are revolutionizing education. Cyberspace has opened an information highway. Technology has gained attention in education today because of its prevalence and its promise to provide low cost education; and it may help some people to participate more easily, to learn more effectively, and to enjoy learning more[23]. Given adequate access to technology, the internet can provide both teachers and students with an ever-growing resource of information. Teachers can introduce and use information from the WWW for instruction and supplement almost any subject matter. It is now possible to deliver lectures, assignments and information to anyone in possession of a modem and computer[24]. The significance of this new technology with respect to education is the ability of the educational superhighway to provide on-demand service; automate assessment techniques and improve instructional strategies. Used effectively, this environment has the potential to level the playing field for education in rural communities that typically lack the resources found in major metropolitan areas, given internet access.

There are many reasons for using the Internet. Some of the reasons include a higher equity of access, an infinite resource, students as active participants, motivational influence of authentic learning activities, student inquiry and cooperative learning, and improved assessment of student progress. Technology adds the ability for students to choose how, when, and where they participate in the learning experience and to bring together a vast wealth of previously unavailable learning resources[13]. On-line education provides the flexibility and efficiency of computer-assisted instruction as well as the individual attention of instructor-guided instruction[15]. The advantages of on-line instruction includes meaningfulness, open communication, organized essential ideas, learning aids, modeling, active appropriate practice, pleasant conditions and consistency[1]. Results also show that on-line use can increase student performance[12]. It has been reported that students using computers focused on tasks for longer periods; found previously boring tasks more interesting; were more eager to participate in and contribute to discussions; asked more questions; and improved their use of the standard conventions of print[10]. There is substantial evidence to suggest that the computer also offers the advantage of making work more stimulating, thereby motivating the individual. However, a major issue of concern to educators is how to effectively design and evaluate different learning formats on the Internet[15].

The use of the Internet by colleges and universities for delivery of distance education is one trend likely to continue. Unlike previous educational trends driven by research and tradition inside the academic community, Internet use for education is enthusiastically supported by forces outside of academe[25]. The most widely used practices are formal courses, self-directed learning, on-line lecture notes, newsgroups, electronic mail, and virtual reality. Both advantages and limitations apply to Internet learners, educators, and institutions. The economy to offer classes to hundreds of learners is balanced by the enormous costs of establishing and maintaining an infrastructure to manage it. The advantage to learners of acquiring customized education at their convenience is offset by the need for expensive equipment to access the curriculum. The list of established universities adopting or seeking to adopt WWW courses for distance delivery is long.

2. Educational Research and Internet Learning

There has been little quantitative evidence examining different learning strategies in the use of Cyberspace. With the threat of a massive influx of uses for advanced electronic media in the classroom, an abundance of qualitative research was performed, resulting in basic subjective conclusions on the possibilities of this technology. Much of this work has been performed in areas concerned with attitudes, gender, aesthetics, and the format of WebPages. In addition, other studies were directed toward hypermedia systems, including elements of presentation such as text structure, readability, fragmentation, and text displays[22]; or the effects of font size in a hypertext environment [8]. Many technical journals described the ideologies of electronic mail, chatrooms, Listservices, and networks [7,2,28,29]. Little is known about instructional design issues that affect student's learning with technology[29] or about the development or acquisition of self-regulation and what can be done to facilitate its development with new technology[27]. After illustrating how today's computing technologies might support how students become self-regulated learners, Winne[30] admits that these hypotheses need empirical study. Therefore the key to instructional power of computer technologies will be in basic research.

Three issues of particular concern to educators emerge in using the seemingly infinite resources available on the Internet and WWW. The first concern relates to information overload and lack of useful instructional format; the second concern relates to identifying the necessary skills and attitudes to enable users to critically evaluate and use the resources; and the third is to effectively design and evaluate different learning formats. If educators are to take full advantage of the interactive characteristics of new technology then we must do more than simply adapt the technology to old styles of pedagogy[20].

Application of appropriate educational learning theories is critical for instruction in any setting. A firm theoretical foundation offers teachers a starting point from which they can build a series of learning opportunities, responding to all styles and encourage a wide range of strategies in order to facilitate successful learning. Innovative approaches plus access to appropriate technologies will lead to the creation of new learning environments that are flexible and provide a custom education for each student, regardless of class size, time and distance constraints, previous preparation, and personal factors. Selection of appropriate technologies should be defined by the desired learning outcomes and students' needs to perform tasks according to their individual styles and strategies, not because the technology may provide an alternate "fun" approach to learning.

The use of the internet as a teaching medium has outpaced the educational research into the efficacy of the media. It is a mistake to emphasize connecting schools to the Internet without considering the kinds of thinking processes students need in order to learn from the information they access. Assuming that learners will be able to activate appropriate learning strategies in any new learning environment without guidance is insufficient to ensure successful learning and development. Like conventional tools' students use to learn,[30] indicate that now they will need to be taught how to use computing technologies. Effective integration of technology as a learning/teaching tool requires present and future educators not only to be trained in computer use but also to have effective and practical integration of useful learning strategies[11]. This type of "self-regulated" learning can become a vital and enhancing part of learning through computers

3. Educational Theory and the Internet

There are three components of an educational theory; a theory of knowledge; (what is knowledge and how is it acquired?), a theory of learning (how do we learn), and a theory of teaching, or pedagogy [14]. The first two components inform the pedagogical choices made by the instructor. There are competing theories of learning that influence how engineering is taught. The traditional theory holds that knowledge is stable and independent of the learner and the corresponding pedagogy is a lecture-based course with content, sequence, and class activities planned by the teacher. The student is a passive participant. However, a theory that holds the the teacher as the primary source of knowledge no longer suffices in a world where knowledge doubles every seven years and 10,000 scientific articles are published every year [13].
A second theory, constructivism, has been embraced by the science education community and has become more commonly accepted in engineering education. This theory holds that the

learner must construct knowledge, the teacher cannot supply it [4]. Constructivism stresses the interaction between learner and the environment and learning is embedded in the context in which it occurs. Learners are encouraged to develop their own understanding of knowledge. Knowledge is a construction of reality. Constructivism is not a theory about teaching It is a theory that encompasses knowledge, learning and thinking[5]. In this scenario, the learner has the active role and the teacher is a facilitator. There is a cultural shift from the importance of possessing knowledge in one's own memory to be able to effectively search for and use the information needed for particular purposes., and this is consistent with a constructivist approach. This is the dominant perspective on learning and has influenced the recommendations of the National Research Council and the National Center for Improving Science Education. A search of the main educational research index, ERIC, produced 2322 entries on a search of the keyword constructivism, since 1990. A similar search in the Engineering Index shows 42 references, 19 of which are from the past two years.

The nonlinear organization of text and graphics on the WWW allows greater user control. However, materials must be structured coherently by establishing associative and conceptual links without eliminating multiple pathways. A constructivist approach permits clear mental representation of concepts and the freedom for each learner to explore them [21]. Recommendations for applying hypermedia research to educational theory for WWW homepage design.include; each destination should be able to stand alone; incorporate appropriate metaphor; provide visual clues indicating users' selections are being processed; include graphic or text-based organizers; include comparative, casual, sequential, associative, exemplary, and componential links; employ labeled and unlabeled links; and use multiple complementary stimuli[26].

Educational researchers have proposed a model of the learning environment that recognizes four distinct and equally important considerations. They are the nature of the material (structure, sequencing, conceptual difficulty), characteristics of the learner (skills, knowledge, aptitudes), learning activities (attention, rehearsal, etc.…) and the desired outcomes (recall, problem solving, etc…)[3.] Educators know that it is a mistake to assume that students automatically know how to learn from texts. Research has shown that students must be taught how to learn from science texts[19.] It is also mistake to assume that all students automatically know how to learn form the internet. Similarly, it is incorrect to ignore the study of the thinking processes students need in order to learn from the information they access. This current study was designed to address the need for empirical data on how technical students can learn from different formats.

This study was designed to provide quantitative experimental data on the role of format in internet learning. The internet is a medium that provides instructors with a mechanism to incorporate comstructivist aproaches and therefore this study is grounded in the constructivist learning theory and was developed to elucidate the role that format has in helping students construct knowledge from the internet as a delivery mode. It sought to answer several questions, including the role of self-regulation in learning from the internet and an exploration of how individual differences such as gender and age may affect learning from the internet. For the purposes of this paper, the feature that will be highlighted is that of the role of format of the material presented to the students.

Method

This study was conducted at the University of Florida using computers equipped with Internet access in various locations on and off campus, in cooperation with the Engineering Research Center for Particle Science and Technology. Engineering/science student volunteers were recruited both on campus and through a posting on the WEPAN web list, to encourage adequate representation of women engineering student participants. Of the 289 students that participated in the study, 145 science and engineering majors completed all of the required forms and were included in the data analysis. The drop out rate was expected due to the unsupervised, voluntary nature of the study. Students first completed the following on-line forms; computer attitude survey (with demographic questions), a Motivated Strategies for Learning Questionnaire (which evaluates self-regulated learners and self-efficacy), a verbal comprehension test (a general indicator of aptitude), an instructional pre-assessment; and an instructional post-assessment (exactly the same as the pre-assessment). The group included 84 male and 61 female students (Table 1) who ranged in age from 18-30. Students represented over 8 disciplines, as indicated in Table 2.

Table 1. Gender Distribution of Participants.

	Males	Females	Total Number
Constructivist Group	44	24	68
Traditional Group	33	32	65
Control Group	7	5	12
Total Number	84	61	145

Table 2. Distribution of Participant Major Study's.

Major	Males	Females	Total
Chemical Engineer	13	7	20
Civil Engineer	5	1	6
Computer Engineer	4	3	7
Electrical Engineer	2	3	5
Environmental Engineer	21	14	35
Mechanical Engineer	22	13	35
Other Engineer	7	10	17
Chemist	6	5	11
Other Sciences	4	5	9
Total Number of Participants	84	61	145

Two instruction modules were developed and offered on-line through the internet The material chosen for the study was an excerpt from an ERC publication entitled *Introduction to Chemicals Used in Particle Systems*[16.] In the traditional format, text was put onto the web in the same prescribed linear sequence as it appeared in the book.. The computer module allowed the participant to examine the information for a duration of their choosing. Each screen offered only two choices, to move to the next page in the sequence or to go back to a previous page to review (Figure 1).

THE NATURE OF THE PARTICLE SURFACE

There are many physical and chemical measurements, which are descriptive of the nature of a particle system. The use of the term "particle system" implies the existence of a finely divided particle phase in a continuous phase. The particle phase is generally one of finely divided solids or liquids and the continuous phase is a liquid such as water, an organic such as alcohol, or an oily liquid such as a hydrocarbon. Physical measurements of particles, e.g., density, porosity, linear size, shape, surface area, etc., are very useful. Such information can be used to understand and predict how to modify the particle system.

<Back			**Forward ->**

Figure 1. Traditional Instructional Module Example WebPage Display.

A true constructivist environment in cyberspace would allow the user to access all areas of the internet. However for the purposes of this study it was not practical and therefore a constructivist environment was defined as a module that allowed the student access to several internal links to build their own knowledge. The material was the same as in the traditional format, but was presented in a way to help students activate their prior knowledge of the subject and participate actively in the learning. They could not only go back or forward but could access the answers to the questions and more to additional material.

THE NATURE OF THE PARTICLE SURFACE

There are many physical and chemical measurements, which are descriptive of the nature of a particle system. The use of the term "particle system" implies the existence of a finely divided particle phase in a continuous phase. The particle phase is generally one of finely divided solids or liquids and the continuous phase is a liquid.

What might be an organic example of this liquid phase?

What physical measurements of particles could be useful?

Page 1 Answers	**Particle Systems**	**<- Back**	**Forward ->**

Figure 2 . Constructivist Module Example WebPage Display

A control group experimental design was used and this group completed all of the online forms and the pre and posts tests but did not read any module material. An analysis of covariance (ANCOVA) was used to determine the format/participant relationships among the presentation formats and variables of gender, age, and several aptitudes.

Results

The results amd statistics for the two study groups and the control group are listed in Table 3 .

Table 3. Descriptive Statistics for Instructional Module Groups.

Group	Pre (max=10)	Post (max=10)	n
Constructivist Format Mean	3.1	5.9	68
SD	2.4	3.2	68
Variance	5.7	10.4	68
Traditional Format Mean	3.8	7.0	65
SD	2.5	2.8	65
Variance	6.3	8.0	65
Control Mean	3.9	4.0	12
SD	3.0	3.0	12
Variance	9.0	8.7	12

Contrary to expectations, there were no significant differences in the post-assessment scores between the two groups exposed to the constructicvist and traditional format. Both groups scored significantly better than the control group. The mean pre- and post-assessment scores for students who completed a constructivist format were 3.1 and 5.9 compared to the mean scores of 3.8 and 7.0 for the students who completed an objectivist format. A score of 10 was possible for these assessments. As a comparison, the mean pre-assessment score for the control group was 3.9 and the post-assessment score was 4.0. Using analysis of covariance (ANCOVA), it was determined that regardless of participant characteristics, post-secondary, technically oriented students were able to learn using two different instructional module formats. The students were able to increase their post-assessment scores significantly over their pre-assessment scores as well as the control groups scores. Therefore there was improvement after completing the on-line instructional module. The finding of increased post-assessment over pre-assessment scores provides support for on-line education via distance learning curriculum using electronic media resources such as the Internet. The important point is that science can effectively be taught using specifically designed instructional modules placed on the Internet.

The only significant difference detected in this study was when age was compared to post-assessment scores. For the range of ages of this study, at age 18, the participant viewing the constructivist instructional module would score 7.1 in a post-assessment, although if projected to the 30 years upper limit of the study's age range, a lower score of 3.9 would be expected out of a possible 10. Therefore, the importance of teaching a particular format on-line to various age groups should be examined prior to implementation of instruction through the Internet.

The results of other elements of this study also concluded that performance on the task was not affected by gender (Table 4), verbal ability or scores on a measure of self-regulated learning.

Table 4. Distribution of Participant Gender and Descriptive Statistics.

Gender	Pre (max=10)	Post (max=10)	n
Male - Mean	3.6	6.4	84
SD	2.5	3.0	84
Variance	6.5	9.0	84
Female - Mean	3.3	6.0	61
SD	2.5	3.3	61
Variance	6.1	11.1	61

ANCOVA analysis confirmed the indication from the descriptive statistics that there was not a significant difference at $\alpha = .05$ between gender groups on post-assessment scores.

Summary

This study showed that technical students may not be format sensitive when it comes to internet learning. It is encouraging that there were no significant differences between gender and post-assessment scores after completing either instructional Gender does not appear to be a performance factor for technically oriented participants learning science-based information on-line through the Internet. This finding is important because there has been previous research ([6]; [9] indicating that gender affects were similar to mathematics and science topics, whereas males when compared to females achieved higher success.

The lack of significant differences in aptitudes and attitudes performance measures such as verbal comprehension, computer attitude and self-regulation of learning is most likely a function of the restricted range of the study group. Students in this group all scored high on these measures.

Discussion

This study accomplished several goals. First, it applied educational theory and research to a fast growing educational delivery mode that is primarily using anecdotal, qualitative methods an assumptions to guide formatting decisions. It also illustrated that technically oriented students at the University level are able to learn from the internet and may not require costly interventions. On the other hand, future research could determine if students who are not successful and drop out of technical fields function as well on these measures and if internet formats tailored to them might improve learning and therefore retention rates of these students. Future research into how students with different aptitudes and attitudes interact with traditional and traditional formats is planned.

Best for Whom?

A cautionary note is that educators should be careful not to use simple statistical methods that may obscure meaningful results. The search for *the* best pedagogical model will necessarily fail. Individual differences must be taken into account. This area is referred to as aptitude treatment interactions (ATI), in which an aptitude is defined as any learner characteristic that impacts how a learner responds to a given learning setting. The treatment refers to any variable in instruction such as pacing, style, modality among others. Figure 3 illustrates ATI.

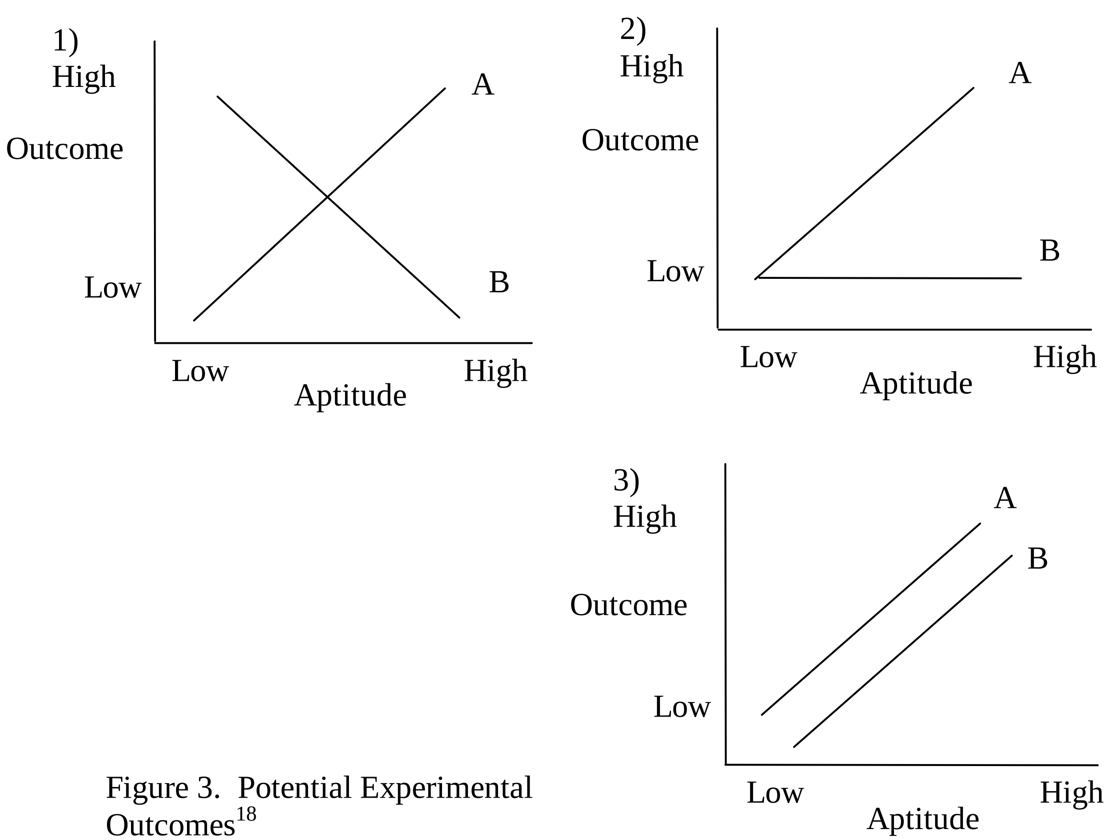

Figure 3. Potential Experimental Outcomes[18]

In the first graph, a traditional analysis looking at the performance of the two groups on the two teaching programs (A & B) based on the average performance score would conclude that the two treatments provided the same benefits to all students. In the second case the average performance score would indicate that treatment A was more effective. Only in the third case does the conclusion based on the total group performance produce a valid conclusion that Treatment A is superior for all students. When using regression analysis that takes into account some learner aptitude (verbal ability, age, spatial ability among many) it is clear that for students who score low on this aptitude, Treatment A is superior, while this treatment is not effective for students with high aptitude. The reverse is the case for treatment B. In the second example, Treatment A only impacts high ability students. This information would be valuable when the cost of implementing a treatment is considered. It may only be cost-effective to offer a particular treatment to a subset of the total group. In the current study, the difference in performance in relation to format varied with age. This is an example of ATI. In this case, there is no one best format, it depended on the age of the students.

Conclusion

This study was conducted to provide empirical evidence of the benefits of a constructivist format on learning in engineering students. It was widely believed among professors involved in the study that this report would illustrate the superiority of the format that provided increased opportunities for students to move throughout the material at their own direction and sequence, It was also noted that this style of presentation was more time consuming to produce and maintain. The non-constructivitst format approximated an instructor scanning in course notes, a much less time consuming process. The results showed instead, that for this group of students, the straightforward, therefore easier and cheaper method of conveying the information was as effective at producing learning as the constructivist option. While initially a surprise, it is less so when the characteristics of the typical engineering student are noted. These students all scored high in both verbal ability and degree of self-regulation in learning. and were able to extract information from either format effectively. Educators developing internet course materials for this group could benefit from being cognizant of the characteristic of these learners when choosing formats. A simpler format that is more cost effective may be adequate., [17]discussed the pedagogic benefits of multimedia presentation in education and asked, “It seems an opportune time for us to stop and ask ourselves whether all this isn’t just hype.” It is important that engineering educators should make pedagogical decisions based on sound educational theory and not ask “Can we.” but “Should we”

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