Patterns of technology adoption and perceptions of virtual laboratories among undergraduate engineering students

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Abstract*: In this pilot study, we examine some of the fundamental relationships between patterns of new technology adoption and perceptions of virtual laboratory environments among undergraduate engineering students. We propose a model for technology use and adoption among undergraduate engineering students. Based on a survey administered to 1065 students at a mid-sized US university, we attempt to answer the research questions: (A) What is the base model of technology adoption among undergraduate engineering students? (B) What are engineering students' perceptions of various attributes of a virtual laboratory (e.g. teamwork, convenience, ease of understanding concepts that are taught, grading)? and (C) Are there any relationships between the base model of technology adoption and students' perception of virtual laboratories? Are such relationships feasible? Our study shows that students perceive the use of any learning technology within the context of a social contract that exists between them and the faculty. Any violation of this contract seems to be perceived negatively and detrimental to the learning process.*

Introduction

Cyber-environments, also referred to as online engineering and science gateways, are gaining importance as platforms for conducting *in silico* experimentation. Many cyber-environments also provide access to remote instrumentation for research and learning. Curricular use of these virtual laboratories provides students with flexibility not only with scheduling and access, but could promote the development of more creative and unrestricted problem solving skills. This increased accessibility can allow students to learn anywhere, anytime, and at their own pace (Bourne, Harris, and Mayadas, 2005). These cyber-environments can also be cost-effective, limiting the demands that traditional laboratories require of equipment and facilities (Balamuralithara and Woods, 2008). While virtual laboratories can remove some of the infrastructural bottlenecks that restrict students from exploring larger real-world problems (Sim, Spencer, and Lee, 2009), it is not clear what factors influence their efficacy as pedagogically useful tools (Ma and Nickerson, 2006; Feisel and Rosa, 2005).

Research Questions

This study examines the following specific research questions:

A. What is the base model of technology adoption among undergraduate engineering students? Several reports published by EDUCAUSE and other researchers have shown that, in general, undergraduate students today are technologically savvy and are comfortable with new technologies. Do undergraduate engineering students differ from the general population of all undergraduate students in terms of technology adoption?
B. What are engineering students' perceptions of various attributes of a virtual laboratory (e.g. teamwork, convenience, ease of understanding concepts that are taught, grading)? How do these perceptions compare to the same attributes in a traditional face-to-face laboratory?
C. Are there any relationships between the base model of technology adoption and students' perception of virtual laboratories? Are such relationships feasible?

Theoretical Framework

Many studies have examined the pedagogical role of virtual laboratories in the engineering and science curricula (Corter et al., 2007; Abdel-Salam, Kauffman, and Crossman, 2006; Ogot, Elliott, and Glumac, 2003). However, these studies are inconclusive about the pedagogical efficacy of virtual environments for teaching engineering and science content. Clearly, a virtual laboratory – regardless of use in simulations or for remote instrumentation – acts as a technological platform for enabling learning. In the context of technology use for learning, many studies have incorporated the theoretical framework supplied by the Technology Acceptance Model (TAM) (Davis, 1989). This model was developed to explain an individual's intention to use a technological innovation, and is composed of two primary predictors – perceived usefulness and perceived ease of use. Since its original proposal, it has been shown to be one of the most reliable predictive models in understanding technology acceptance (Teo, Su Luan, and Sing, 2008; Venkatesh and Bala, 2008; Walker and Johnson, 2008; Landry, Griffeth, and Hartman, 2006).

The theoretical basis for this study is provided by a combination of the Technology Acceptance Model (TAM) (Davis, 1989) and the Theory of Diffusion of Innovations (Rogers, 1995). Using perceived usefulness of a technology and its perceived ease-of-use, the TAM deals primarily with the technology itself. On the other hand, the Theory of Diffusion of Innovations is used to describe the adoption or acceptance of a new innovation among several adopter groups. It incorporates the impact of social dynamics on technology adoption. Research question A is informed primarily by the theory of Diffusion of Innovations, while research question B is built on TAM. Research question C explores the interaction of the two theoretical frameworks.

Methodology

A survey was developed based on the combination of TAM and the Theory of Diffusion of Innovations. It was administered to undergraduate students at a mid-sized southeastern university in the United States. Questions on the survey regarding prior technology use and adoption were adapted from Salaway et al. (2008), while those pertaining to the specific aspects of the laboratory were piloted locally and further refined. The survey was posted on Surveymonkey™. Faculty teaching undergraduate engineering and science courses during Fall 2008 were asked to either post the link to the survey on their course websites or e-mail it directly to their students. A total of 1065 undergraduate students (44.4% female, 55.6% male) from engineering (N=509), science (N=333), and liberal arts (N=223) responded to the survey. The median age of the respondents was 19. We focus primarily on the 509 engineering students for the purposes of this study. Additional demographic data for the engineering students, including academic year, gender, and ethnicity are shown in Table 1. Overall reliability of the survey instrument as calculated by *Cronbach's Alpha* was *0.764*. In all statistical comparisons throughout the study, we use $p \leq 0.01$ as the level of significance.

Table 1: Demographic Information for the 509 Engineering Students

Academic Year		Gender		Race / Ethnicity	
1st	51.3%	Male	74.8%	Caucasian	85.1%
2nd	19.3%	Female	24.2%	Asian / Pacific Islander	4.3%
3rd	11.4%			Not specified	4.1%
4th	12.4%			African American	3.5%
5th or more	5.7%			Hispanic	1.6%

Results

The data from our pilot study indicate a high level of student use of various technologies, specifically with regard to the everyday use of the Internet (96.9%), social networking services (71.3%), and word processing (52.3%). Furthermore, 56% of engineering students reported spending an average of four or more hours online every day. However, strong majorities indicate never having accessed a blog (41.9%) or a virtual world such as Second Life (83.9%), despite the widespread availability of these technologies (Technorati, 2008; Second Life, 2008).

While students spend a significant amount of time using various online technologies, the rate at which they report adopting and using new technologies offers some interesting trends. All participating students were asked to indicate how early they adopt new technologies – reported in Figure 1.

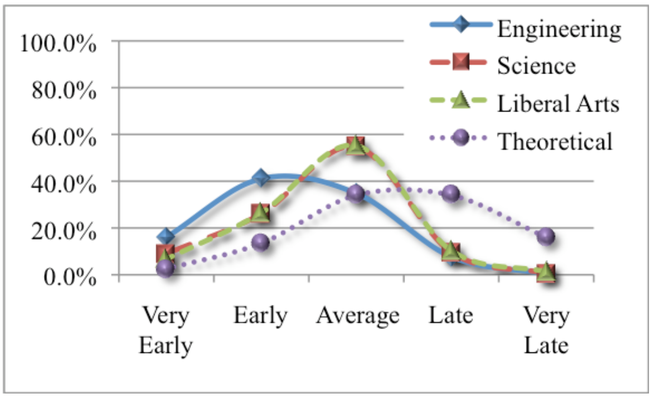

Figure 1: Rate of technology adoption among undergraduate students

To address research question A, we compared engineering students' responses to the theoretical values predicted by Roger's Theory of the Diffusion of Innovations (Rogers, 2005) and with the responses of students from other disciplines. Engineering students differ significantly from the theoretically predicted values and from science and liberal arts students. A chi-squared analysis of the distributions indicated that engineering students adopt new technologies much faster than science and liberal arts students ($\chi^2 = 59.797$; $p < 0.01$). A larger majority of engineering students classify themselves as early adopters (Figure 1). This deviation essentially means that engineering students may easily absorb curricular innovations involving new technologies.

Despite engineering students' adopting new technologies much earlier and their high level of technology use in general, in the context of virtual laboratory use their initial, unexperienced perception is largely negative. Students report a low likelihood of enrolling in a virtual laboratory if one were offered instead of a traditional F2F laboratory (Research question B). On the survey a virtual laboratory was defined as a laboratory that used the Internet as a medium for conducting experiments. Further, students were grouped according to their rate of new technology adoption (very early / early = early adopters; average = mainstream; very late / late = late adopters). A chi-squared analysis of the distributions indicated no significant differences by rate of new technology adoption ($\chi^2 = 27.90$, $p = 0.032$ – please note, that our level of significance is set at $p \leq 0.01$). The majority of students, regardless of their rate of new technology adoption, were unlikely to enrol in a virtual laboratory (Figure 2).

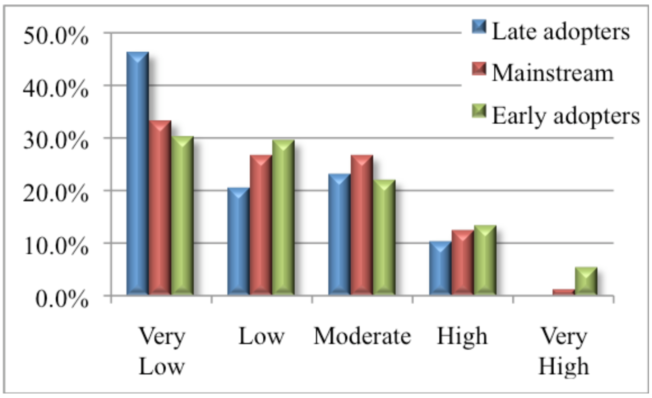

Figure 2: Likelihood of engineering students enrolling in a virtual lab by rate of new technology adoption

In order to further examine research question B, we asked students to rate their agreement with how well the laboratory promoted six specific attributes shown in Table 2. A Likert scale (1 – strongly disagree to 5 – strongly agree) was used. Students rated both the traditional F2F laboratory and the virtual laboratory. As many of the students had no experience with a virtual laboratory, they were asked to rate their perception (as opposed to experience) of how well a virtual laboratory would promote each attribute identified in Table 2. The ratings indicate significant differences between their perceptions of the two types of laboratory environments on all six attributes (Table 2). In open-ended responses eliciting the advantages of virtual laboratories, students seemed to predominantly address issues of easy access. There was not a single response that suggested that students felt that the virtual laboratory environment would impact their learning positively.

Table 2: Student ratings for specific aspects for each laboratory environment

	F2F Laboratory		**Virtual Laboratory**		**t-test for significance**	
	Mean	Standard Deviation	Mean	Standard Deviation	t-value	p-value
Lab-lecture correlation	2.78	1.075	**3.20**	0.724	-6.596	< 0.01
Relevance of the material	**3.12**	1.010	2.65	0.794	7.349	< 0.01
Easy to understand	**3.14**	0.969	2.54	0.889	9.386	< 0.01
Convenient	3.04	1.054	**3.81**	0.927	-10.798	< 0.01
Promotes teamwork	**3.80**	0.879	1.84	0.811	32.366	< 0.01
Accurate grading	**3.25**	1.111	2.83	0.819	6.030	< 0.01

Further analysis was performed on student ratings for the virtual laboratory attributes based upon their level of new technology adoption (Figure 3). With the exception of teamwork ($\chi^2 = 13.28$; $p = 0.01$), no significant differences were found between students in different groups of new technology adoption.

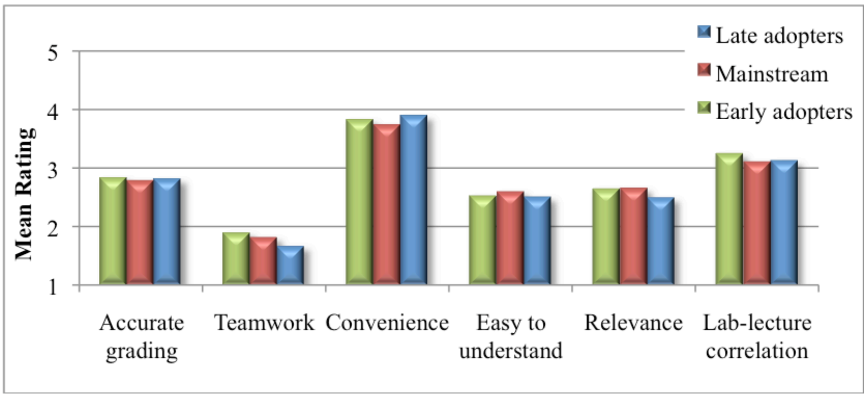

Figure 3: Mean ratings for virtual laboratory by new technology adoption

Discussion

Engineering students have indicated that they adopt new technologies at a rate earlier than predicted theoretically by Roger's bell curve. Furthermore, engineering students seem to be more ready to absorb new technologies in the curriculum than science and liberal arts students. Despite the early adoption trends and heavy use of online technologies, the majority of engineering students in this study indicate a very low likelihood of enrolling in a virtual laboratory *if given a choice*. According to these results, earlier levels of new technology adoption do not necessarily predict higher likelihoods of enrolling in a virtual laboratory. Technology adoption within students' private spaces and learning spaces seems to come through as mutually exclusive. Also, very rarely do engineering students have the option of selecting the technologies that they will be exposed to within the curricula. Perhaps, if provided with a choice of technologies, these trends may be different.

In terms of attributes directly related to learning within a virtual laboratory, our results show significant differences in comparison to face-to-face methods. The traditional laboratory was rated significantly higher for presenting materials that students deemed relevant, easy to understand, for promoting teamwork, and providing accurate grading. Nearly 80% of students indicated that the virtual laboratory would not be conducive for teamwork. Additionally, 46% of respondents indicated that topics and concepts presented in a virtual laboratory would be tougher to understand than those presented in a traditional F2F laboratory. This suggests that although students perceive the virtual laboratory as being easy to use in terms of effort required, they do not perceive the virtual laboratory as useful for enhancing their academic performance. Many responses to open-ended questions suggested that face-to-face interactions provide better scaffolding and were more conducive for teamwork. Also, we reason from the responses that students may equate a virtual laboratory with a *violation of social contract between faculty and students*.

Conclusions and Future Directions

This pilot study seems to suggest that engineering students perceive online technologies as falling largely within two spaces – private and learning. Clearly, engineering students spend a substantial amount of time online and are active everyday users of a variety of technologies including social networking services, word processing, and the Internet. However, in the context of experimenting with virtual laboratories for their learning, it seems that they would much rather not adopt these technologies at a fast rate. In particular, we hypothesize that this negative perception of virtual laboratories may be rooted in the social contract that exists between students and faculty. They expect face-to-face interactions with faculty and associate this with better learning. Also, their lack of experience with virtual laboratories seems to make them pre-disposed to viewing this modality as largely negative. Given that most students do not have the choice of selecting technologies that may be used for their curriculum, it seems faculty have to pay a lot more attention to what perceptions students bring into the learning environment. Clearly, as budgets and cost concerns become critical, newer technologies will be employed in the engineering curriculum. Our study suggests that perhaps using a well-planned phase-in approach to provide students with a wider range of choices when it comes to learning technologies may lead to more positive experiences for students. Also, all students participating in this study valued teamwork highly, and indicated by a significant amount that a virtual laboratory environment would not promote this critical attribute. The traditional laboratory may require less effort on the part of students to stay on task, and is a place where students are not connected to all of the other services that they may already use while they are online. Not having all of these connections may help them stay more focused in the traditional F2F laboratory, leading to a perception of a better learning environment.

As this was an exploratory pilot study, more research is needed to answer fully research questions A, B, and C identified in this paper. We are currently in the process of refining the instrument used in this study to ground it more fully within the theoretical framework identified here. It is possible that several of the factors measured in this study may have a specific role in determining students' likelihood of choosing to enrol in a virtual laboratory. This study represents a first step in better understanding how engineering students view cyber-environments in general and what specific characteristics of the cyber-environment may be important to them. We are currently using factor analysis to develop more specific questions regarding each of the six broad attributes measured in this study.

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