AC 2011-88: APPLYING THE INNOVATION IN ENGINEERING EDUCATION FRAMEWORK: ASSESSING THE IMPACT OF INSTRUCTIONAL TECHNOLOGY

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Applying the Innovation in Engineering Education Framework: Assessing the Impact of Instructional Technology

Abstract

One component in systematic educational innovation is examining the use and impact of instructional technology within the engineering undergraduate curriculum [1]. Instructional technology such as laptops, used in conjunction with software such as OneNote and Dyknow, course management systems, and social networking platforms can provide students and faculty access to shared learning spaces and allow for mobile learning. Regular use of these tools within the engineering curriculum by a cadre of faculty trained to use them effectively can provide students with opportunities to challenge traditional ways of thinking, creating changes in the educational environment [2,3]. National attention has been directed at the need to examine the use of instructional technology more closely, including whether use of these tools has the desired effect on the teaching and learning process [1]. This paper describes the assessment methods currently being employed at a Research I university that are designed to examine the effectiveness of an undergraduate Tablet PC laptop requirement as it relates to systematic change in the nature of undergraduate teaching and learning.

Introduction

Previous studies acknowledge that instructional technology can be used to challenge traditional ways of teaching and learning. New modes of communication and presenting material through different electronic mediums can encourage interactions and exchanges between and among faculty and students, creating a more engaging learning environment [4,5,6]. Technology-based tools can provide simulation and problem-based learning opportunities and access to video and audio clips, wikis, and blogs can be used to examine a variety of viewpoints. Instructional technology affords multiple access points for learners and instructors leading to more time on task as time and space issues are reduced [7].

The literature provides less information about how the application of instructional technology can be assessed to determine whether and how these tools are changing the pedagogy being used and the manner in which students are learning. Lack of information about different assessment approaches makes it difficult for educators that are in the midst of trying to institute innovative approaches and determine whether those approaches are effectively accomplishing stated aims and goals. At the same time, assessment of curriculum and instruction, especially innovative approaches in the design and delivery of these two areas, has been identified as a fundamental element in effective engineering education [1].

This paper describes the assessment methods currently being employed within a College of Engineering (CoE) at a Research I university that are designed to examine the effectiveness of an undergraduate Tablet PC laptop requirement as it relates to systematic change in the nature of undergraduate teaching and learning. How the data and information collected as part of the assessment efforts are being shared and used for different initiatives tied to improving the educational environment for engineering undergraduates is also discussed. Examples of the data are provided so that other institutions can see the information being collected and the application of those findings as it relates to the goals and objectives of the project being assessed. The focus of this paper is on the assessment process rather than focusing on a specific research question and the results of study in relation to that research question. The proposed assessment model can be used by other institutions or agencies that are interested in assessing the impact of instructional technology.

Background

Virginia Tech's College of Engineering (CoE) made the Tablet PC a requirement for all engineering undergraduates in the fall of 2006. The Tablet PC is a conventional notebook, with a keyboard for typing, with the option to rotate and fold the screen so that a stylus can be used to make handwritten notes and drawings in a similar fashion to pen and paper. When used with other instructional software, the design allows for students to participate in class presentation and activities by drawing responses and questions and sending them to the instructor for display and further discussion. Students can collaborate with one another in the same manner during class as well as outside of the classroom. The Tablet initiative was seen as a way to have undergraduates become adept in utilizing cutting-edge technology while at the same time enhancing their learning experience through exposure to instructional technology that is theoretically linked to increased engagement with course content. Utilization and effective deployment requires pedagogical approaches that effectively incorporate this form of instructional technology into lessons. Given the increased opportunities that this type of instructional technology can afford in terms of engagement and collaboration within the learning environment, the CoE developed an assessment plan that would help determine the extent to which this technology was changing the nature of teaching and learning. The plan was designed in collaboration with representatives from the School of Education at Virginia Tech.

Conceptual Framework

The assessment approach tied to this initiative is informed by best practices and includes the fundamental qualities of a comprehensive assessment program, including the idea that the evaluation, reporting, and use of results are an ongoing, cyclical process. This process is intended to be a transparent, public process involving many different stakeholders and it is designed to understand and improve student learning. The methodology uses a systematic process to collect and analyze data. Results are then used to make informed decisions [8,9,10].

To that end, constructivist learning theory provides a conceptual framework for this assessment process. This theory is well suited to the outcomes of the Tablet initiative which are focused on how students and faculty use the Tablet as well as the relationship of that usage to important learning behaviors. Constructivist learning theory posits that interactions between learners as well as with the instructor can aid in cognitive development. This premise is supported by studies that show students who engage with one another and their instructor actively develop skills related to knowledge acquisition and transfer [11,12,13,14]. Constructivist learning theories also presume that students are active developers and processors of information [15]. Students' motivation to learn and the learning strategies they employ to engage with course content being presented as well as other elements within the educational setting can influence the degree to which students are successful [15]. How students process information garnered from textbooks, lectures, and other course materials can be influenced by the degree to which they use such learning strategies such as rehearsal, elaboration or paraphrasing, and organizational behaviors such as outlining or creating diagrams and tables. Application of new knowledge to content currently being studied plays a role in students' success as well [15]. Within this paradigm there are key Tablet features that are theoretically linked to important learning behaviors identified by constructivism (refer to Table 1).

Table 1. *Linkages Between Tablet PC Features and Constructivist Learning Theory*

Tablet Features	**Constructivist Teaching and Learning**
• Electronic notes • On line collaboration • Multiple representational modes • Interactive classroom presentation • Ready access to internet • Ready access to database, statistical, design and other software	• active elaboration and integration of concepts • teamwork, memory and learning strategies • symbolic, spatial, textual representation of problem e.g. science • student input, active engagement, problem solving • critical evaluation of info & autonomy • organize info and scale thinking

How faculty employ the Tablet and related instructional technology and the pedagogical implications for the classroom environment and student learning is an integral component that is also part of this assessment design. Rogers' [16] Diffusion of Innovations Theory suggests that several factors may increase the success of faculty adopting new pedagogical practices and has been used to understand the factors encouraging as well as prohibiting faculty use of the Tablet. When an innovative technology is introduced, it is communicated among members of the social system and then adopted over time. This process is what Rogers [16] called diffusion of innovation. The decision process for users deciding whether or not to adopt the new technology follows five steps: knowledge, persuasion, decision, implementation, and confirmation. During this process, users' decision to adopt as well as the speed of technology diffusion depend on following attributes: 1) relative advantage (is the new technology better?), 2) compatibility (is the new technology consistent with past experiences?), 3) complexity (is the new technology difficult to understand?), 4) trialability (can users experiment with the new technology on a limited basis?), and 5) observability (are the results visible to others?) [16,17]. According to Rogers [16], adoption of technology will be more likely if the complexity of the technology is reduced but relative advantage, compatibility, trialability, and observability are maximized.

Discussion

Given the scale of the assessment efforts, quantitative and qualitative methods were used to examine the degree to which changes in the nature of teaching and learning were taking place, including: a college-wide survey of all engineering undergraduates, focus groups among students that include both first-year students and graduating seniors, case studies of different courses that implemented changes in activities so that the Tablet could be used, individual faculty interviews, a faculty survey, and a faculty focus group held with one engineering department. Given the focus on instructional technology and motivating factors as well as barriers to adoption evaluation of the infrastructure including classroom space, support personnel, and policies are also examined as part of this process. Over five years the assessment process has evolved with refinement of the assessment materials taking place during the course of the project.

Quantitative Measures. Since starting the Tablet PC requirement in 2006 the CoE has monitored student use of the Tablet as well as the degree to which use is related to certain educational outcomes through an online student survey administered to engineering undergraduates. The survey examines students' use of the Tablet PC and its relationship to self-regulated learning behaviors as well as the degree to which students engage in collaborative learning utilizing the Tablet features. Since its inception, the survey has gone through various iterations. The survey has consistently contained a section that had items from the Motivated Strategies for Learning Questionnaire (MSLQ) which is theoretically tied to the constructivist learning theory framing our assessment plan [3]. The MSLQ is a validated and reliable instrument designed to measure the degree to which students engage in cognitive and metacognitive behaviors that are related to active processing of information. Items also ask students the degree to which they use others such as peers and instructors when learning [15]. The MSLQ items are Likert-scale formatted questions that include response options related to frequency of use of certain learning strategies and behaviors. In addition to the MSLQ items, the instrument has asked consistently asked respondents how often they utilize the Tablet in their courses and included open-ended questions that ask students to describe their experiences with the Tablet in their courses and the advantages they see related to using the Tablet. During each year of administration the reliability and validity of the survey has been re-established among the population that it was administered to. Demographic data such as current year within the engineering program and students' comfort level with using technology are solicited from respondents. Revisions to the survey that have occurred over the four year period have included incorporating questions from the EDUCAUSE Center for Applied Research (ECAR) [18] questionnaire so that a one-time snapshot of students engagement with technology could be compared to national benchmarks.

At one time the survey was administered twice a year to students, at the beginning of the course as well as at the end of the semester and the questions measured learning behaviors being used in a specific course. More recently, the survey has been administered once a year to students. Revisions in the survey administration were done to increase response rate and to provide a more realistic picture of student use over the course of the academic year and across courses they are enrolled in.

The online faculty survey has also evolved over the course of the assessment process. The instrument is administered to all faculty members of the COE and was designed to obtain faculty members' practices related to instructional technology more generally as well as the Tablet specifically and pedagogy employed in their courses. Topics in the survey included classroom activities, teaching objectives, instructor behaviors, instructional technologies used, and motivations/barriers towards adopting instructional technologies. The survey included estimation, forced choice, multiple choice, Likert-type, and open-ended questions.

Qualitative Methods. The assessment efforts have also included case studies of individual faculty utilization in their classes of the Tablet PC. These studies were designed to determine whether pedagogical approaches that used this instructional technology led to increased student engagement with course content and used observation along with the student survey described previously to measure that change.

In the fourth year of the initiative, assessment efforts broadened and deepened in scope. Focus groups among students and faculty were undertaken in addition to the surveys being conducted. In order to obtain first-hand experiences with both new users and more experienced users of the Tablet PC focus groups were conducted with freshman and senior level students in the COE. The questions were designed to obtain students' experiences with Tablet PCs, including their usage of and opinions about the Tablet PC and its features. One engineering department that had several faculty that incorporated the Tablet into their courses was asked to participate in a focus group. The protocol was designed to have faculty describe how and why they used the Tablet as well as barriers to usage. In addition, individual interviews were conducted with faculty as well. Four COE faculty members representing a variety of disciplines were identified by the research team as lead adopters of the Tablet PCs to be interviewed. These faculty members were chosen because of their consistent classroom use and long-term experience with Tablet PCs. The interview questions were designed to obtain the faculty members' experiences with Tablet PCs, including how and why they started using tablet PCs, how the tablet PC has changed their approach to instruction, how they currently use tablet PCs in their classroom, and any possible barriers they see towards adoption by other faculty members and students.

The college infrastructure has also been examined through this assessment process. Alliances with internal and external stakeholders are monitored to determine their effectiveness. This includes university organizations such as the Communications Network Services Group, Learning Technologies, and the Faculty Development Institute. External partners, such as hardware and software vendors, are brought into the assessment process as recommendations from users are shared. This includes recommendations on technology as well as on price of the Tablet models used. Since the Tablet can be coupled with different instructional software for an enhanced learning-teaching experience it is important to examine the functionality, price, and reliability of this software. This is done through classroom observations, questions included on faculty and student surveys, and also during focus groups.

Application

This section discusses how the assessment framework has provided the data necessary to determine whether the outcomes and objectives of this initiative are being achieved. Examples of the findings are provided as well as how those results have been used to design initiatives to further positive changes in the nature of teaching and learning and address areas of opportunity.

In total, the assessment efforts have provided a map that let us determine how the Tablet requirement has changed the nature of teaching and learning through examination of multiple data points over time. Descriptive statistics of the surveys and more detailed analyses including looking at the correlation between usage of the Tablet and important learning behaviors among students have been conducted. All interview audio recordings were transcribed verbatim. The transcripts were coded and analyzed based on grounded theory. The Diffusion of Innovations Theory [16] served as the basis for the coding scheme. In total, this information has been put into reports internal to the CoE as well as published externally in conference proceedings and journals. As assessment results are shared findings are being used to inform curriculum and pedagogy, leading to systematic change in the educational environment.

Based on the data collected over the past several years the College of Engineering has instituted a variety of initiatives to encourage both student and faculty use. For example, in the most recent survey conducted in 2010 we found that students did not report frequent use of the Tablet features (refer to Table 2).

Table 2. *Tablet PC Function Use: Frequency Scale: 1 (Never) - 4 (Frequently)*

	Mean	SD
e-ink to mark slides provided by the instructor	2.39	1.17
Instructor presented using e-ink	2.30	1.08
e-ink to take notes using OneNote	2.30	1.25
e-ink to create diagrams	2.16	1.09
Imported web-based information into notes	2.00	1.1
Shared notes/slides with other students	1.94	0.98
e-ink to take notes with another program	1.93	1.06
e-ink was used to grade homework or projects	1.90	1.05
To respond to interactive class exercises using polling/voting	1.77	0.88
To respond to interactive in-class exercise using written responses	1.74	0.91
Special note take capabilities of OneNote	1.69	0.97
Shared electronic whitespace with other students	1.56	0.83
Audio recording of lectures/discussions using OneNote	1.23	0.59

In order to encourage greater use the college has developed student support services and tutorial services through a student led technology team. Through peer training we hope that the instructional technology will be more readily adopted and used by students. These same initiatives are hoped increase the degree to which students also use their Tablet to engage in learning behaviors linked to constructive learning theory such as rehearsing and memorizing information, critical thinking skills, organizing class materials, elaborating on information provided by the instructor, active involvement in and regulation of learning (i.e., metacognitive self-regulation), and engaging with peers to share and learn information (refer to Table 3).

Table 3. *Learning Behavior Scales: Response to Item Asking Students to Respond How Frequently They Use Their Tablet to Do the Following* (N=560)

Learning Behaviors Scale (α=Chronbach's alpha) Individual Survey Items	M	SD
Critical Thinking Scale (α=.837)		
I often questioned things I heard or read in the course to see if I found them convincing.	2.62	1.112
I reread my course materials as a starting point and tried to develop my own ideas about it.	2.37	1.108
Whenever I read or heard an assertion or conclusion in class, I thought about possible alternatives.	2.39	1.105
Rehearsal (α=.773)		
I studied by reading my notes over and over again.	2.76	1.184
I make lists of important items for this course and memorize the lists.	2.20	1.113
I memorized key words to remind me of important concepts from this class.	2.69	1.220
Metacognitive Self-Regulation (α =.860)		
I asked myself questions based on my notes and other study materials to be sure I understood the material I was studying in class.	2.59	1.153
I tried to change the way I studied in order to fit the course requirements and the instructor's teaching style.	2.68	1.221
When studying for the class I tried to determine which concepts I didn't understand well.	3.04	1.203

Table 2 (continued)
Learning Behavior Scales: Response to Item Asking Students to Respond How Frequently They Use Their Tablet to Do the Following (N=560)

Learning Behaviors Scale (α=Chronbach's alpha) Individual Survey Items	M	SD
When I was confused taking notes in class, I made sure I sorted it out afterwards.	2.73	1.179
Organization (α = .773)		
I made simple charts, diagrams, or tables using the Tablet PC to organize course material.	2.18	1.248
To study, I reviewed my notes and made an outline of important concepts.	2.54	1.229
To study, I went through my notes to find the most important ideas.	3.24	1.250
When I studied the readings for this course, I outlined the material to help me organize my thoughts.	2.14	1.126
Peer Learning (α =.739)		
When studying for this course, I tried to explain the material to a classmate or friend.	2.86	1.209
I tried to work with other students from this class to complete the course assignments.	3.03	1.318
Elaboration (α = .797)		
I used my Tablet PC to make connections between readings and lecture notes.	2.18	1.189
I try to apply ideas from web-based sources to other class activities such as lecture and discussion.	2.29	1.118
When I studied for this course, I used my Tablet PC to pull together information from lecture, readings, and discussions.	2.63	1.29

Note: Response options ranged from 'Never=1' to 'Very Frequently: Almost Every Week=4'.

More detailed analyses using Pearson's Correlations found that students who used the Tablet were significantly more likely ($p \leq .001$) to demonstrate important learning behaviors. Initiatives have been designed to relay information about the positive educational benefits of students and faculty employing this type of instructional technology to students and parents of engineering students, especially those about to enroll in their first semester through newsletters and other publications.

By raising awareness of the educational benefits among students the CoE hopes that engineering undergraduates continue to utilize the Tablet given the relationship between use and increased self-regulated learning behaviors. While the results related to the relationship between Tablet PC use and self-regulated learning behaviors are promising, the CoE also hopes to encourage learning to a greater extent through collaboration with peers and instructors. Increasing student and faculty use of the Tablet features that facilitate collaboration such as polling and sharing of documents that have been inked are mediums through which this type of interaction might take place. In order to more specifically target collaborative learning behaviors the CoE will be conducting focus groups with students to determine how they use their Tablet to share information with one another or what barriers serve to prevent the sharing of information between students and faculty.

Assessment efforts have shown that successful applications of the Tablet and related pedagogy require faculty adoption and effective use of this new technology. In order to facilitate this, results from assessment efforts have been used to identify benefits as well as barriers in using the Tablet (refer to Table 4). This information is being shared among departments in the hopes that barriers can be addressed through collective efforts.

Table 4. Benefits and Barriers of Tablet Use Reported by Faculty

Benefits	Barriers
• Increased student interactions and engagement in class	• Lack of tangible incentives
• Helpful visualization features in DyKnow	• Inconsistent performance of hardware/software
• Better student understanding	• Issues with classroom infrastructure
• Active participation of shy students	• Lack of compatibility with preferred pedagogy
• Easier demonstrations and more interactive lectures	
• Team collaboration out of class	
• Easy digital annotations	
• Virtual office hours	
• Access to lectures after classes	
• Ability to import figures into DyKnow: increases quality of course notes and saves time	
• Allowing faculty members to cover more material in less class time	
• DyKnow offers a variety of tools for visual learners: highlighters, pointers, drawing tools with templates, resizing, capture, screen sharing, in-class polling	

At the same time, the college is offering professional development opportunities for faculty that focus on specific features of the Tablet that have been identified by colleagues as having especially useful pedagogical applications. These are being offered through the Faculty Development Institute (FDI) at Virginia Tech University which provides free training courses to faculty members on how to use the Tablet and its various functions and through the CoE Instructional Technology support team, which consists of graduate students, provides one-on-one training sessions with faculty members. This will hopefully lead to further diffusion of this instructional technology across departments.

Interviews with faculty members revealed that the greatest use was occurring among our first-year courses. The degree to which entry-level courses and instructors can serve as an example for upper-level courses is also being explored. The CoE plans to conduct focus groups among faculty who teach first-year students to determine the pedagogical approaches they use with the Tablet and how those can be applied to more advanced level courses.

Infrastructure issues that may prevent faculty use and what factors might serve to motivate faculty to adopt Tablet PCs is an integral part of the pedagogical approaches they employ. One obstacle that hindered some faculty members from using the Tablet in class was that some of the older classrooms did not have enough power outlets for students to charge their computers. To overcome that, the CoE plans to provide each classroom with a box of extension cords so that each student and faculty member will have access to constant power.

Summary

This paper focused on the sharing the assessment process being used to determine the impact of an innovative form of instructional technology on the nature of teaching and learning. By looking at how students learn using this device, how faculty use this form of instructional technology to teach, as well as the infrastructure that supports the educational environment the assessment process provided detailed information that has allowed this CoE to systematically gauge in what ways instructional technology is part of changes taking place in the nature of teaching and learning. By sharing examples of the information collected as part of this assessment effort as well as sharing how the assessments were conducted the dialogue can continue with regard to how the impact of instructional technology can be evaluated. Others can use the information to consider how to assess the impact of instructional technology on the learning environment and how to use information collected to inform initiatives underway to support educational innovation.

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