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Student use of the Tablet PC: Impact on student learning behaviors

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ABSTRACT

Pedagogical approaches that incorporate learning technologies into lessons and coursework have had promising results in relation to students' motivation to learn. Tablet PCs have been identified as one form of instructional technology that can facilitate learning among engineering undergraduates since this medium allows for drawing on the computer screen, a potentially valuable way for students to annotate prepared lesson documents, replicate graphs and other visual content, and take and share notes that include diagrams. This study examines the degree to which student and faculty use of the Tablet PC is linked to important student learning behaviors. Results of the study reveal that frequency of student use of the Tablet is related to increased engagement in engineering courses. Practitioners can use this information when considering what instructional technology to utilize in engineering courses and what pedagogical approaches to pair the technology with in order to facilitate student learning.

Keywords: Instructional technology, student engagement, student motivation

BACKGROUND

Student motivation plays an integral role in attainment of course learning goals as well as overall achievement. Motivation is largely understood to be influenced by both personal characteristics and factors that are present in educational settings (Beck 2000; Hancock, Bray, and Nason 2002). Pedagogy that actively involves students in the learning process can serve as a form of motivation and can increase student performance (Zimmerman and Martinez-Pons 1988; Eysink, de Jong, Berthold, Kolloffel, Opfermann, and Wouters 2009). In particular, pedagogical approaches that incorporate learning technologies into lessons and coursework have shown promising results in relation to student motivation to learn (Hancock, Bray, and Nason 2002; Schneckenberg 2004), including studies among engineering undergraduates (Steif and Dollar 2009).

One way that motivation to learn can be observed is by examining how engaged students are in the learning process, conceptualized as self-regulated learning behaviors. Students who are engaged make connections with pre-existing knowledge, have an organized approach to identified learning activities, and can monitor their understanding of the content presented using critical thinking skills (Como and Mandinach 1983; Duncan and McKeachie 2005). How students process information garnered from textbooks, lectures, and other course materials can be influenced by the degree to which they use 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 is another learning strategy that is a form of engagement (Pintrich and Garcia 1991). These activities are initiated by students and sustained during the learning process (Pintrich and Schunk 1996). Student motivation plays a role in students' success in a given course. Undergraduates who utilize strategies that require processing of information being presented and who use metacognitive skills such as setting goals and monitoring their own comprehension are more likely to do better on a variety of course-related tasks including papers and exams. They also achieve higher end of course grades (Perry, Hladkyj, Pekrun, and Pelletier 2001; Pintrich 2004; Pintrich and Garcia, 1991).

In terms of factors present in the educational setting, pedagogical approaches used by instructors have the ability to influence student learning. A framework that is student-centered rather than teacher centered has been shown to facilitate student learning (Schneckenberg 2004). Among engineering undergraduates, a student-centered approach can enhance students' motivation and confidence related to skills and knowledge necessary for problem-solving (Deek, Kimmel, and McHugh 1998). Approaches that engage students in thoughtful dialogue with peers about course content are also linked to student performance (Johnson and Johnson 1999). Students that utilize peers and engage in cooperative learning are more motivated to learn and have higher achievement than students who are less likely to demonstrate collaborative behavior (Hancock 2004).

Learning technologies used for instruction including such things as computers, software, interactive multi-media, and online resources have been shown to enhance student learning (Kadiyala and Crynes 2000; Wang and Reeves 2007). Technologies such as these can influence pedagogical practice, for instance shifting the focus from teaching to learning (Laudrillard 1979; Kolb 1998; Schneckenberg 2004). In educational settings technology can also be used to enhance the transmission and production of knowledge. When used appropriately, learning technologies can also aid in the organization of course material, allow for increased communication and collaboration between instructors and students, and increase access to course related material as there are fewer constraints placed by time and location (Schneckenberg 2004). Technology-based tools can provide simulation and problem-based learning opportunities as well as access to video and audio clips that can be used to examine a variety of viewpoints (Bourne, Brodersen, Campbell, Dawant, and Shavi 1996). This type of assisted learning has been shown to have promising results among engineering undergraduates. For instance, computer assisted design software has helped engineering undergraduates learn and apply concepts that they will need to know when they are employed in industry (Wiesner and Lan 2004).

Tablet PCs are one form of technology being employed in the engineering classroom. The Tablet PC is a conventional notebook, with a keyboard for typing, that has 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. The hardware design, along with specialized software and a suitable networking infrastructure, 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. While primarily descriptive in nature, previous studies focusing on engineering undergraduates have shown that the capabilities associated with the Tablet can serve as a means to facilitate a variety of pedagogical approaches and invite student participation and collaboration with one another (Lohani, Castles, Lo, and Griffin 2007; Tront, Filer, Scales, and Prey, 2009) as well as with the instructor (Li and Bellarmine 2009; Roschelle, Tatar, Chaudbury, Dimitriadis, Patton, and DiGiano 2007; Bowman and Benson 2009; Farahani and Ulig 2009). It is believed that the capabilities associated with the Tablet can assist engineering undergraduates who are enrolled in courses that cover material that is often mathematically and graphically intensive (Frolik and Zurn 2004; Moore and Hayes 2008). Surveys conducted at one university reveal that students report an increase in their attention with the Tablet PC (Brophy and Walker 2005) and their confidence related to applying concepts learned in class when using the relatively easy note sharing capabilities associated with the Tablet PC (Cunningham, Sexton, and Williams 2009). Other studies examining the Tablets' role in the understanding and attitudes towards conceptual design are inconclusive (Nguyen, Wise, Bilen, and Devon 2007).

Overall, beneficial results are most readily seen when there is a match between the learning technologies, pedagogical techniques and learning objectives (Kadiyala and Crynes 2000). Matching student motivation to the correct instructional approach has also shown to be important as the two factors influence undergraduate student achievement (Hancock, Bray, and Nason 2002). With this in mind, Tablets, and learning technologies more generally, must be thoughtfully utilized and incorporated into educational setting if they are expected to produce significant benefits (Hancock, Bray, and Nason 2002). The value in terms of educational outcomes associated with learning technologies, including Tablets, is increased if students' self-regulated learning behaviors are promoted through use (Steif and Dollar 2009).

While research has shown that learning technologies have the potential to promote student engagement (Schneckenberg 2004) fewer studies have examined student use of learning technologies and the relationship of that use to student motivation and self-regulated learning behaviors (Fister and McCarthy 2008). This study is designed to address this gap in the literature. The investigation examines the use of instructional technology among engineering undergraduates at a Research I university and the relationship of such use to specific student learning behaviors. Specifically, this study examines student and faculty use of the Tablet PC and features associated with the hardware and software such as the stylus and inking capabilities, the faculty-student and student-student interaction capabilities, and the relationship of this use to self-regulated learning among students. The research questions guiding this study include, a) Is there a relationship between student and faculty use of the Tablet PC and desired student learning behaviors? b) Is there a difference in the self-regulated learning behaviors between students who use the Tablet more frequently and those who use the Tablet less frequently?

In this study learning behaviors being examined include: rehearsal (e.g., repetition of words or concepts), organization (e.g., outlining), elaboration (e.g., paraphrasing, summarizing), critical thinking (e.g., application of new knowledge to situations), metacognitive self-regulation (e.g., setting goals, monitoring one's own comprehension), and peer collaboration (e.g., using a study group or friends to help learn) (Duncan and McKeachie 2005). Student use of the Tablet is defined as the number of courses as reported by students that they have used the Tablet in during their undergraduate enrollment. Faculty use of the Tablet is defined as the number of courses students reported faculty using the Tablet during the students' enrollment.

ASSESSMENT OF TABLET PC: STUDENT USE AND LEARNING BEHAVIORS

Virginia Tech's College of Engineering made the Tablet PC a requirement for all engineering undergraduates in the fall of 2006, making it one of the first colleges to adopt this instructional technology. The College of Engineering at Virginia Tech includes the Department of Computer Science and thus this study includes both traditional engineering students as well as computer science students. Throughout the rest of this paper the term engineering student will be meant to represent both groups. The Tablet 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 increases in self-regulated learning behaviors and collaborative learning (Tront et al., 2009).

An online survey administered to all engineering undergraduates enrolled at Virginia Tech during the Spring 2009 semester was used to measure student use of the Tablet as well as the degree to which use is related to student learning behaviors. Following approval from the Institutional Review Board, all engineering undergraduates enrolled at the university were invited to participate by email. The email invitation included a link to the survey and was sent at the end of the spring term. Asking students to complete the survey at the end of the academic year was done in order to provide a more realistic picture of student use over the course of the academic year and across courses they were enrolled in throughout their time as a student at Virginia Tech.

The survey was primarily made up of items adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Duncan and McKeachie 2005, Pintrich 2004). The MSLQ is a valid 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 (Duncan and McKeachie 2005). The MSLQ adapted items used in this study are Likert-scale formatted questions that include a range of five response options related to frequency of use of certain learning strategies and behaviors in specific engineering courses using their Tablet. Response options range from 'Never' to 'Very Frequently: Almost Every Week.' Items related to Rehearsal ask students how often they memorize key words or concepts. Organization was measured by items that asked students how often they used their Tablet to pull together notes, diagrams, and other important information related to class. Learning behaviors associated with Elaboration were measured by items that asked respondents how often they used their Tablet to make connections with other materials including web-based resources. Critical thinking was measured by items that asked students how often they questioned ideas or information presented by the instructor. Metacognitive self-regulation was measured by four items that asked respondents how they monitored their learning and sought clarification if they were confused. Peer collaboration was measured by two items that asked respondents how they used peers during the learning process.

In addition to the MSLQ related items, the instrument used for this study asked respondents how many courses they used the Tablet in during their enrollment. Students could select from a range of frequencies starting with one course to as many as five or more courses. Faculty use was measured by an item that asked student respondents how many courses faculty used the Tablet in during their enrollment. The same response options were provided to students for this item. Additional items on the instrument ask respondents which features of the Tablet they used including the e-inking features as well as polling, or whether faculty used the Tablet to provide graded feedback on assignments.

Demographic data such as current year within the engineering program and the students' comfort level with using technology are solicited from respondents.

The survey was previously piloted to undergraduate students enrolled at the university during the 2007 and 2008 academic years. This process allowed the items to be refined so that the questions could target student use of the Tablet PC in and outside of their courses. Following the pilot the instrument used for this study incorporated items that were shown to provide a high degree of reliability and validity.

Respondents to the survey included 560 undergraduate students, providing a response rate of about 12%. The students represented a relatively equal proportion of students by class year ranging from first year students to senior engineering undergraduates.

Data Analysis

Descriptive and multivariate statistics were used for the data analysis. The MSLQ is designed such that scales can be created from the items included on the instrument that relate to different learning behaviors. Six scales were created from the variables on the instrument that related to the learning behaviors examined in this study including: Critical Thinking, Rehearsal, Elaboration, Organization, Metacognitive Self-Regulation, and Peer Learning. Each scale was ensured for reliability. The items included in each scale as well as the Cronbach's alpha for the scale are listed in Table 1. Following creation of the scales, Pearson's correlations and t-tests were conducted.

RESULTS

The data were analyzed to determine to what extent student and faculty use of the Tablet were related to different learning behaviors and whether there were differences in the motivation to learn among students based on reported use of the Tablet PC. Results related to this analysis are reported in this section.

Pearson's correlations reveal that there is a significant positive relationship between the number of courses students use the Tablet in and identified student learning behaviors (refer to Table 2). In particular, learning behaviors associated with Elaboration show the strongest relationship with student use ($r=.433$, $p<.001$). Students' reported faculty use and self-reported frequency of learning behaviors reveal a positive but much weaker relationship.

Next, the data were analyzed to determine specifically which features of the Tablet were related to student learning behaviors. Results reveal that overall there is a statistically significant and positive relationship between student use of the Tablet features and learning behaviors. The strongest relation-

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
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'.

Table 1: Learning Behavior Scales (N = 560).

	Courses Faculty Used Tablet $r =$	Courses Student Used Tablet $r =$
Elaboration	.120**	.443***
Org	.127**	.356***
Peers	.087*	.327***
Critical Thinking	.076	.241***
Rehearsal	.113**	.256***
Metacognitive Self-Regulation	.184***	.311***

$^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$

Table 2: Correlation Between Number of Courses Tablet Used In and Learning Behaviors (N = 560).

ships were seen among use that was student initiated (i.e., e-ink to create diagrams) and the learning behaviors of Elaboration and Organization. For instance, using the Tablet to import web-based information into notes, special note taking capabilities of OneNote and e-ink to create diagrams were items that had the strongest relationship with Elaboration and Organization. There were positive but much weaker relationships between use that was faculty driven (i.e., to respond to interactive in-class exercises) and the learning behaviors being examined in this study (refer to Table 3).

Finally, students were grouped according to use. Students were categorized as high users if they indicated they used the Tablet in three or more courses. Students were categorized as low users if they indicated they used their Tablet in two or fewer courses. This grouping was based upon a typical course load by semester for engineering undergraduates, with the majority of students enrolling in at least four courses each fall and spring academic semester. Descriptive statistics reveal that high users and low users are distributed across class year (refer to Table 4) with high users found more frequently among first year students when compared to upperclassmen. This distribution is expected since the Tablet requirement had not yet propagated across the full four years of the program by the time this survey was taken.

Once students were grouped the data were analyzed using t-tests to determine if there were differences between these two groups in learning behaviors. Results reveal that high users of the Tablet were significantly more likely to indicate that they employed self-regulated learning behaviors in that they had higher mean scores on five of the six scales including: Organization, Metacognitive Self-Regulation, Critical Thinking, Rehearsal, and Peer Learning (refer to Table 5).

	Elaboration	Organization	Peers	Critical	Rehearsal	MCReg
Instructor Presented Using OneNote.	139**	.101**	.078	.062	.073	.132***
e-ink to take notes using another word processing program	.343***	.272***	.164***	.218***	.241***	.229***
e-ink to mark slides provided by the instructor	.384***	.352***	.254***	.258***	282***	.322***
e-ink to create diagrams	.400***	.364***	.256***	.268***	.265***	.282***
e-ink was used to grade homework or projects	.229***	.162***	.163***	.183***	.166***	.152***
Share notes/slides with other students	.374***	.335***	.277***	.258***	.301***	.283***
Shared electronic whitespace for group activities	.332***	.235***	.272***	.301***	.295***	.290***
Import of web-based information into notes	.421***	.380***	.276***	.321***	.335***	.314***
Special note taking capabilities of OneNote	.402***	.407***	.218***	.292***	.327***	.254***
To respond to interactive in-class exercises	.283***	.247***	.207***	.218***	.240***	.223***
To respond to interactive in-class exercises using student generated responses	.268***	.236***	.232***	.216***	.230***	.223***

$^{*}p \leq .05$; $^{**}p \leq .01$; $^{***}p \leq .001$

Table 3: Correlation Between Use of Tablet Features in Engineering Courses and Student Learning Behaviors (N = 560).

	High Users*** N(%)	Low Users N(%)
First Year	101 (33.2)	43 (16.7)
Second Year	120 (39.5)	71 (27.6)
Third Year	67 (22.0)	115 (44.7)
Fourth Year or higher	44 (7.8)	28 (10.9)

$^{***}p \leq .001$

Table 4: Differences in Usage by Class Year (N = 561).

DISCUSSION AND IMPLICATIONS

While several studies have provided descriptive data about how Tablet PCs are used in engineering classrooms, this study provides more detailed information about specific learning behaviors that are

	High Users M(SD)	Low Users M(SD)
Elaboration	2.73(.96)	1.92(.89)
Organization	2.80(.85)**	2.18(.91)
Peer learning	3.26(.98)***	2.56(1.16)
Critical Thinking	2.65(.84)*	2.27(.94)
Rehearsal	2.77(.89)**	2.28(.99)
Metacognitive SR	3.02(.83)***	2.44(1.07)

*$p \leqslant .05$; **$p \leqslant .01$; ***$p \leqslant .001$

Table 5: Differences in Learning Behaviors Between Student Groups by Use (N = 560).

most readily utilized by engineering undergraduates in conjunction with this form of instructional technology. Results of this study identify student use of instructional technology as playing a role in student motivation to learn. Pedagogical approaches that employ Tablet PCs as well as student initiated usage of the Tablet are related to several educational benefits.

Having access to a Tablet PC may allow engineering undergraduates to utilize key learning strategies that may not have been possible otherwise, motivating students to learn and apply course concepts in new ways. Patterns associated with student use reveal that students who readily employ the Tablet and its related features are more likely to indicate that they use learning strategies that aid in comprehension and application of course related material. Use of the Tablet allows for student engagement with the course material. E-inking features facilitate student organization of course content but also allow students to elaborate on the information being presented by the instructor. Students use the stylus to create diagrams and mark notes and instructor generated PowerPoint slides provided during class. Active learning strategies such as these encourage students to process the information being presented and make sense of it. Students have the opportunity to question the information to see if they understand or need further clarification in relation to the material being presented as they jot down notes on the computer screen. Use of the Tablet also allows students to study on their own, with students indicating that they used the Tablet to access online resources that aided in their understanding of course material.

In addition to the learning strategies that are primarily used by individuals, engineering students who use the Tablet in three classes or more over the course of their undergraduate enrollment are also likely to benefit from peer learning. Collaborative learning environments are documented as having important educational benefits (Johnson and Johnson, 1991). Across majors and programs, engineering undergraduates reported that they are most likely to use the software OneNote to collaborate with peers using their Tablets. Providing feedback and sharing notes allows for a critical exchange of information to take place and provides another venue for students to think about and make sense of course content. However, the results from this study did not show that students use the Tablet for peer learning to the same extent that they use their Tablet for other learning behaviors such as organization and elaboration. This may be due to the fact that the pedagogy used in the classrooms does not facilitate peer learning and the exchange of information between student groups. It may also be an indication that the software currently available is not as conducive to peer learning as it needs to be in order to engender regular student use. Additional exploration of this trend could provide useful information to instructors.

A limitation of this study was that it focused on student and faculty use of one form of instructional technology and the relationship of this use to self-regulated learning among students. Future studies could look at other forms of instructional technology to see whether they also have a positive impact on student motivation to learn and whether different learning behaviors are used based on the form of technology employed. In addition, it would be interesting to compare how student learning that occurs with instructional technology is distinct from learning through traditional non-computer methods and usage or non-usage of technology impacts different learning behaviors. Additional limitations include how usage was measured in this study, focusing on the number of times students used the Tablet in their courses. Future studies could examine proficiency of usage which would more clearly delineate how the Tablet was being used by students and its relationship to different learning outcomes.

Reported faculty use of the Tablet in courses was low and faculty use of Tablet features such as polling or providing feedback using the Tablet did not demonstrate as strong of a relationship to student use of self-regulated learning behaviors. However, the findings are strongly suggestive that if faculty were to incorporate additional active learning strategies into their lessons students would have an opportunity to use their Tablets more, potentially increasing student motivation and engagement in engineering courses. Faculty can use the information provided by this study to consider ways in which to incorporate the Tablet into their courses as it provides an indication of the learning strategies most often used by students. If faculty members do not currently utilize Powerpoint presentations that students can annotate with the stylus, faculty may consider integrating this into their lectures and discussion of class material. Faculty may also consider how to use the Tablet in ways that allow students to interact with them. Exchanging feedback and providing opportunities in class or out of class through virtual office hours that allow students to ask questions or demonstrate their understanding through use of the Tablets interactive features could provide a chance for students to exercise self-regulated learning behaviors associated with critical thinking and meta-cognitive self-regulation.

One limitation of this survey was the response rate. Conducting this same survey at other universities or comparing trends across years could also provide a more comprehensive picture of how technology can influence student learning behaviors. A survey of the next cohort of students is currently in the plans at Virginia Tech. Qualitative studies could provide more detail in relation to how students use the Tablet and how they interact with one another as well as the instructor through electronic mediums provided by learning technology. Successful applications of the Tablet and related pedagogy require faculty adoption and effective use of this new technology. To that end, interviewing groups of engineering faculty about how they use the Tablet as well as what motivates them to utilize learning technology in their teaching would help identify specific factors that facilitate or impede faculty use and would provide additional context in terms of what pedagogical approaches might increase certain student learning behaviors.

While not reported in this paper, related studies have shown that faculty who teach first-year engineering courses in the College of Engineering where this study took place make the greatest use of the Tablet PC, embedding this form of technology into the learning experience for the majority of engineering courses students complete in the first year (Kothaneth and Amelink, 2011). This may explain why first year students were found more readily among the high users. In light of these findings, results suggest that if the technology is used effectively by faculty in several courses, the positive impact on student learning and engagement could increase. This study did not explore differences in learning behaviors by class standing. Future studies could examine more closely the degree to which entry-level courses and instructors use the Tablet and compare that to upper-level use among students and faculty. Such studies could consider how faculty and students use the Tablet as students advance through their coursework and whether differences in pedagogical approaches in beginning versus advanced level courses makes a difference in student adoption of learning behaviors and motivation to understand course content.

CONCLUSIONS

Overall, the conclusions illustrate the relationship between student learning behaviors and the instructional technology that was the focus of this study. Students' motivation to learn and engage with engineering course content increases in learning environments where students make use of Tablet PCs. While students indicate that they use the Tablet with relative frequency, use could potentially increase if faculty employed Tablet features more readily in their engineering courses. Tablet features such as the e-inking capabilities allow students to access, process, and share information in different ways. These activities are strongly correlated to learning behaviors that facilitate student success. Practitioners can use this information as they consider implementing or engaging in initiatives that are designed to utilize learning technologies as a means to encourage student motivation and successful attainment of course objectives.

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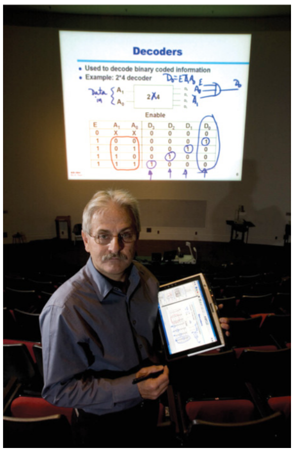

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