AC 2010-1961: CAN PEN TABLETS BE USED TO IMPROVE THE PERFORMANCE OF PLACE-BOUND ENGINEERING STUDENTS?

Dale Buechler, University of Wisconsin, Platteville

Associate Professor, Department of Electrical Engineering, Wisconsin Teaching Fellow 2009 - 2010, Electrical Engineering Assessment Chair 2008 - Present, ASEE Mathematics Division Chair 2006-2007, ASEE Mathematics Division Program Chair 2005-2006

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Abstract

Office hours are an essential component of undergraduate engineering education. In a traditional program, student questions that arise during the completion of assigned work are handled through face to face office hours. Our collaborative electrical engineering program, which allows students to complete their entire four-year degree on site, is taught primarily by on-site faculty and is supplemented through distance education offerings taught via streaming video (SV). We have found that most of our place-bound students, both in distance and face to face offerings, underutilize office hours due to outside constraints. Since most engineering students have a difficult time verbalizing what they are having trouble with, it is difficult for these students to get their remote questions answered adequately without being able to share the same piece of paper. In our SV offerings, we have experimented with web conferencing software to obtain equivalent office hours for distance students and found that this was successful, provided that both the instructor and the student had tablet PCs. Unfortunately the cost of tablet PCs provides a barrier to both students and to academic institutions. In response to this need, a Scholarship of Teaching and Learning Project (SoTL) was designed to investigate the use of a relatively inexpensive technology, pen tablets, to improve the access of place-bound students to assistance from instructors and fellow students. Each participating student in the fall section of analog electronics was provided with a pen tablet for the semester and agreed to participate in think-aloud sessions with their instructor. They also were encouraged to use this technology to regularly communicate with their instructor and fellow students. Students were provided with surveys after each think-aloud session and at the end of the semester. Survey results include their feelings about the technology, their use of the technology, and their thoughts about its future use. Data about student improvement on think-aloud topics and overall class performance is presented.

Background

The University of Wisconsin-Platteville began offering their undergraduate electrical engineering program to place bound students and working adults at two of the two-year campuses within the university system in the Fall of 2006[1,2]. Recently the program has been extended to students at the other eleven two-year campuses within the university system via streaming video (asynchronously). The program is designed so that students can earn a bachelor's degree without ever leaving their local two-year college campus. Nationally, very few electrical engineering programs offer undergraduate courses via distance and the few that do are taught synchronously and require at least some of the work to be completed on campus[3,4,5]. Courses at the two original collaborative sites are delivered by on-site faculty and are supplemented by streaming-video offerings. Streaming-video offerings are delivered via state-of-the-art technology along with courseware management systems and face to face portable lab instruction. Most of the students at the collaborative sites are balancing jobs and/or family commitments which restrict their travel to campus as well as their interaction with fellow classmates and their instructor. To date most of that experience has been with non-traditional students who are receiving face to face instruction[6]. With the addition of distance students to the program, this task has been made even more challenging. In the future, not only will there be

non-traditional students in the course with limited student-teacher face to face contact, but also some students will take the course asynchronously (little or no face to face contact).

One of the major issues in the education of place-bound engineering students is office hours. Most engineering students have a difficult time verbally explaining the troubles they are having with a homework problem or project. During traditional office hours students typically draw circuit diagrams, figures, mathematical equations, etc. to try to convey their difficulties to their instructor. If the student cannot meet with the instructor face to face, it is difficult for students to get their questions answered adequately. Simple e-mail communication with instructors or fellow students does not work very well, especially as the courses begin to get more difficult conceptually. An alternative approach that allows either instructor and student or groups of students to share the same piece of electronic paper is needed.

After surveying the engineering literature for possible solutions to this problem, it was determined that most groups utilized either web-conferencing[3] or interactive whiteboards[4,7] for office hours. Two approaches have been used: shared applications and question and answer. In the shared-application approach, both instructor and student have access to the same application, have a means of communication, and have a pen input device. Most institutions using this approach utilize tablet PCs for both instructor and student together with web conferencing software. The University of Wisconsin-Platteville Engineering College tried using Adobe Connect Pro Web Conferencing in three hybrid distance engineering courses in the spring of 2009. For this limited trial run, each distance student was provided with a loaner tablet PC. Although the initial results of this study, which involved a small number of distance students, were encouraging, this solution will not be sustainable. The university only has the resources to supply a limited number of loaner tablet PCs for this purpose and therefore they are currently available to distance students located at some of the sites (remote sites without on-site engineering faculty). For the rest of the distance students, a question and answer approach has been employed. In this approach only the instructor has a tablet PC and the students can see the examples being done by the instructor and ask questions (by audio or texting). Those using this latter approach have reported mixed results in the literature[3,4,5]. In our experience, the former approach, which allows for two-way communication on the same electronic piece of paper, works much better in higher-level engineering courses. The current approach creates issues of equity in the short term (some have tablet PCs/some do not) and could cause access issues in the future if the distance student program requires students to have a tablet PC (only those with financial means will be able to afford them). A more economical solution that will allow better communication with instructors and fellow students is needed.

Development of Pilot Study

One problem area for many engineering students has been the transition from introductory classes where the laboratory projects follow a set procedure to design classes where students learn to apply what they have learned in class to new situations and learn to create designs to meet project specifications. This process is difficult for many students because there is not just one correct answer and the design process involves trade-offs. The traditional education process for upper-level engineering students is based on continuous feedback to correct student errors and answer student questions. This poses a significant problem for place-bound students, who

due to outside constraints often underutilize office hours, one of the primary sources for traditional-student feedback. This is an even bigger issue for students that are taking upper-level engineering design courses at a distance. Therefore a pilot project was developed to investigate a potential solution to this problem.

Analog Electronics is the course that was selected for the initial stage of this pilot project. It is the first course in which students are introduced to non-linear devices such as diodes and transistors. Mathematical modeling of these non-linear devices, which also vary as a function of frequency and temperature, is much more complicated. In the laboratory portion of the class, the students must apply what they have learned in class and use it to design and build circuits that meet prescribed specifications. Often students do not understand the interrelationship between the theory, discussed in lecture, and application (design). This lack of student understanding the big picture is not unique to engineering. It has been seen in other STEM areas as well[8].

Having selected the context of the study, a relatively inexpensive technology, USB pen tablets, was selected to investigate as a possible mechanism to improve student access to office hour help and to help from fellow students. It was hypothesized that if student access to help is facilitated, student performance in the course will improve.

This Scholarship of Teaching and Learning (SoTL) Project focused on the following two questions:

> i) To what extent can pen tablets be used to improve the access of place-bound students to assistance from instructors and fellow students?
> ii) To what extent will improved student access to help result in improved student performance?

Since the course selected for this pilot study was anticipated to be quite small, each participating student would receive their own pen tablet. In addition each participating student would be provided a basic tutorial on the use of the pen tablet and agreed to complete two think-aloud[9] sessions with the instructor during the semester. Other usage of the pen tablet technology during the semester was encouraged, but was not required.

The think-aloud sessions were an on-line one to one meeting where both the student and the instructor could use pen tablets to write on a shared electronic whiteboard. The first session utilized a free on-line whiteboard site (http://www.imaginationcubed.com) provided by General Electric (GE) together with a telephone. This free site did not require registration or passwords, thus making it a potential resource for student to student communication as well. The second session used a commercial web-conferencing software (Adobe Connect Pro) together with a telephone (students did not have access to headsets at the time of the study). Use of this site had to be initiated by the instructor.

Prior to the start of the semester, assessment data from the last two offerings of analog electronics was analyzed using grounded theory[8] resulting in the list of most common student conceptual errors shown in Table 1. Two problematic concepts: transistor biasing for maximum signal swing and transistor frequency response were selected for the think-aloud sessions.

Difficult Concepts for Past Students in Analog Electronics
1. Frequency response
2. Transistor biasing
3. Small-signal analysis
4. Voltage regulation
5. Multi-diode circuits

Table 1. Top five difficult concepts for students in analog electronics (Spr. 2007, Spr. 2008)

For both think-aloud sessions the students were asked to use their pen tablet to write out their solution to a specific homework problem while verbally explaining the steps that they were taking. The students were asked questions throughout the solution process, provided direction as needed, and provided with feedback. This approach is an on-line equivalent of having each student go to the board to solve a problem.

Results

Since this collaborative program started relatively recently, the class only had six place-bound students taking the course face to face. Originally the course was scheduled to be offered as a hybrid course to both face to face and remote students, however, the streaming-video portion of the class was cancelled toward the end of summer due to lack of demand. All six face to face students elected to participate in the study (n = 6). The first think-aloud session made use of the free GE whiteboard site (Figure 1). As a follow-up, the students were given a quiz testing their understanding of the overall concept of biasing bipolar-junction transistors (BJTs) for maximum-signal swing. Overall the students demonstrated an understanding of transistor biasing although

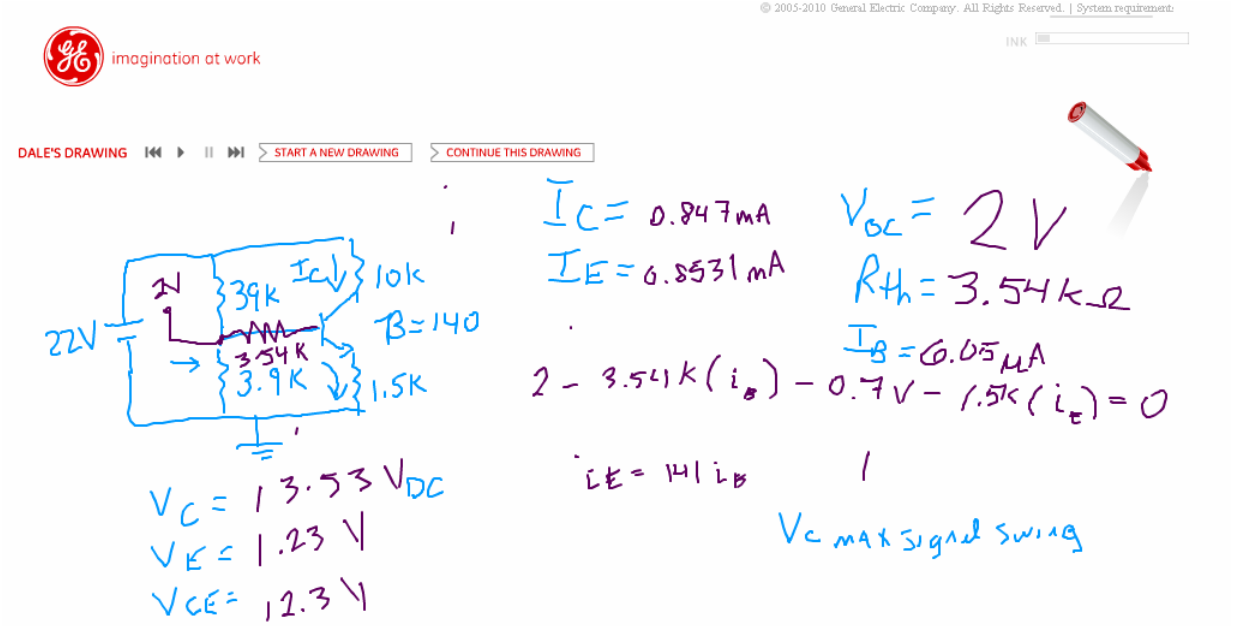

Figure 1. Copy of whiteboard work from the first student-instructor think-aloud session conducted on www.imaginationcubed.com

some still had some difficulty with the concept of maximum-signal swing (See Table 2). The average quiz score for the pen tablet session material (used in place of traditional homework) was 80.83% as compared to the combined averages for all other quizzes (69.79%).

Quiz #	1	2	3	4 (pen tablet)	5
Avg. Score	62.08%	68.33%	72.50%	80.83%	76.25%

Table 2. Average Quiz Scores for Analog Electronics Fall 2009.

The second think-aloud session utilizing the Adobe Connect Pro web-conferencing software covered the concept of MOSFET high-frequency response (See Figure 2). On the final exam, a problem was given involving the frequency response of MOSFETs. The average score on this problem was 96.1% as compared to the average final exam score of 78.9%. Table 3 shows a comparison of average test scores on similar material in prior years without the use of pen-tablet think-aloud sessions.

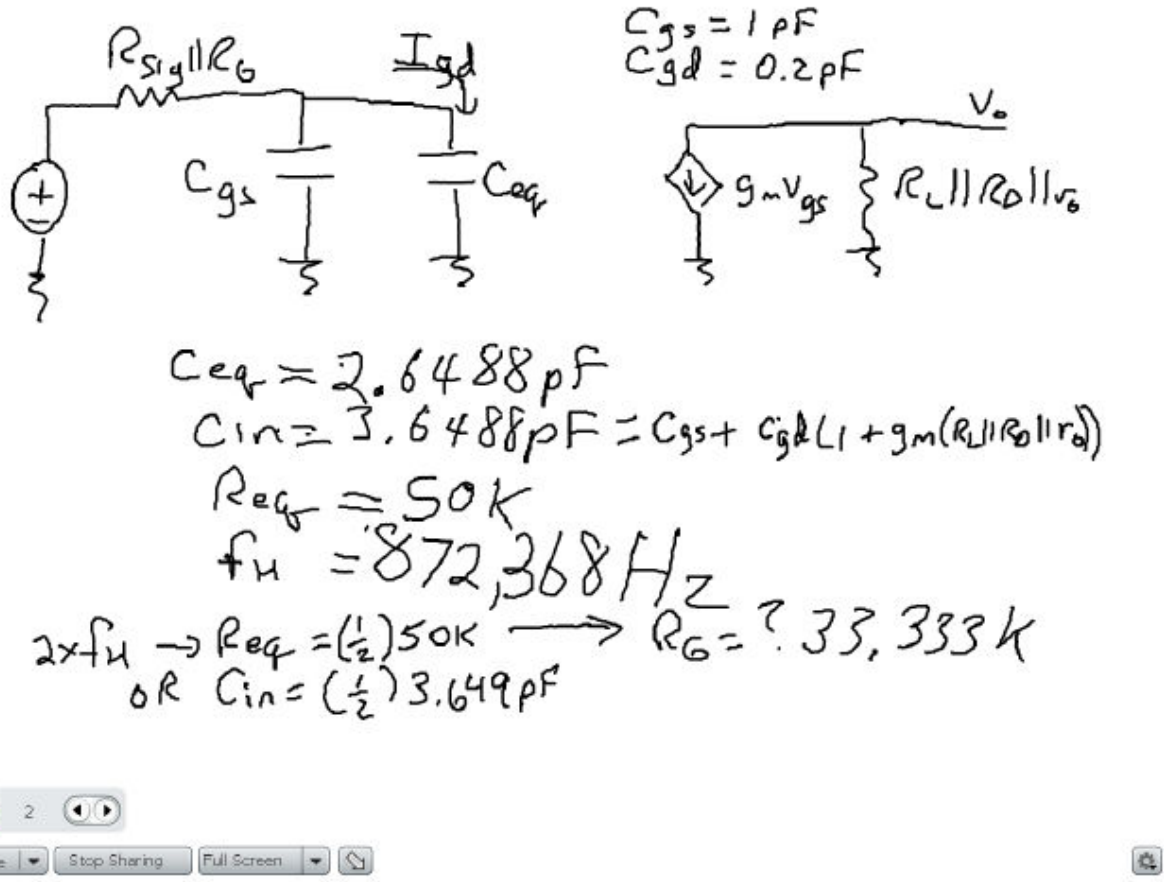

Figure 2. Copy of whiteboard work from the second student-instructor think-aloud session conducted using Adobe Connect Pro.

Concept	Fall 2007 (HW)	Fall 2008 (HW)	Fall 2009 (Pen Tablet Think-Aloud)
Biasing for Max. Signal Swing	85.83% (exam)	63.13% (exam)	80.83% (quiz)
MOSFET High-Frequency Response	72.08% (exam)	76.67% (exam)	96.1% (exam)

Table 3. Comparison of student exam/quiz performance on similar topics using traditional homework versus pen-tablet think-aloud sessions

At the conclusion of the semester each of the students was given an end of the semester survey to determine their feelings about using pen tablets and think-aloud sessions for their coursework. Table 4 shows the results for frequency of pen-tablet usage by students during the semester.

How many times did you use the pen tablet to communicate with your instructor (exclude the 2 required think-alouds)?				
0	1-2	3-4	5-6	7 or more
66.7%	33.3%			
How many times did you use the pen tablet to communicate with fellow students?				
0	1-2	3-4	5-6	7 or more
33.3%	66.7%			
How many times did you use the pen tablet for assigned homework?				
0	1-2	3-4	5-6	7 or more
33.3%	50%	16.7%		

Table 4. Frequency of pen-tablet use during the semester (End of Semester Survey Results)

The Pen tablet tutorial session was helpful				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
50%	50%			
Pen tablets were useful in this course				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	50%	16.7%		
Pen tablets provided improved access to assistance from my instructor				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
50%	16.7	16.7%	16.7%	
Pen tablets provided improved access to assistance from fellow students				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
	83.3%		16.7%	
Pen tablets were useful in the completion of assignments				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	50%		16.7%	
Having a Pen tablet facilitated my ability to get my questions answered				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	33.3%	16.7%	16.7%	

Table 5. Usefulness of pen tablets (End of Semester Survey Results)

The results in Tables 5 and 6 show the results of Likert-scale surveys about the usefulness of pen tablets and their future use respectively. Tables 7 and 8 provide demographic and learning style results that were collected to obtain potential insight into survey responses.

Pen tablets should be used for future courses at this location				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
50%	33.3%	16.7%		
Pen tablets would be useful in future distance course offerings				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
83.3%		16.7%		
Pen-tablets should be retained to improve communication with instructors				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
83.3%		16.7%		
Pen-tablets should be retained to improve communication with fellow students				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
66.7%	16.7%	16.7%		
Pen-tablets should be retained for inserting handwritten work into assignments				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	33.3%	33.3%		
Pen tablets would be as useful as tablet PCs for the purpose of communicating with my instructor and fellow students				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	33.3%	33.3%		
Think-alouds should be used in future courses				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
66.7%	33.3%			

Table 6. Future use of pen tablets (End of Semester Survey Results)

Age				
Traditional student		**Non-traditional student**		
50%		50%		
Hours worked in a typical week				
0	**< 20 hours**	**20-29 hours**	**30-40 hours**	**Over 40 hours**
33.3%		50%		16.7%

Table 7. Demographic Information

I understand information best by doing something with it				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
50%	50%			
I understand information best by thinking about it quietly first				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%	16.7%	50%		
I prefer to solve problems by well-established methods				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
50%	33.3%		16.7%	
I prefer to look at the big picture rather than the details				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
16.7%	16.7%	66.7%		
I tend to remember what I see				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
	66.7%	16.7%	16.7%	
I tend to remember what I read or hear				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
16.7%	50%	33.3%		
I prefer to follow logical stepwise paths in finding solutions				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
66.7%	33.3%			
I prefer to solve complex problems by understanding the entire system first				
Agree Strongly	Agree	Neutral	Disagree	Disagree Strongly
33.3%		66.7%		

Table 8. Learning Style Information

Discussion

The initial results of this pilot study on pen tablets are primarily positive. It is important to note that although all the students in this course were taking this course face to face with the instructor, most of these students have had at least one prior point to point distance education experience and realize the importance of being able to get their questions answered. They also understand that since they are located at the collaborative site (away from main campus), they will most likely be taking at least one distance course in the future. This vested interest explains the 100% participation in this study.

The students that participated in this pilot study were split evenly between traditional- and non-traditional-age students. It is therefore not surprising that the survey results for those listing non-traditional age in their demographic information tended to more skewed towards the agree or agree strongly responses since these students have other commitments such as family and work that need their attention and reduce their access to traditional office hours. It is also not surprising that the majority of students work over 20 hours per week. The only negative results came from traditional-age students who are attending school on a full-time basis. Even though instructor access is not a huge issue for full-time students taking a course face to face, almost all the students, both traditional and non-traditional, saw value in the use of pen tablets for distance education courses in the future (See Table 6).

The "frequency of pen-tablet use" number during the semester was somewhat disappointing. Most of the students only did what was requested of them for the study (the tutorial, the two think-aloud sessions, and one communication with a fellow student). While the students did not embrace the technology, they did show initial interest in checking out the technology and most did provide valuable feedback. The initial student feedback from the first think-aloud session indicated that the pen tablets were useful for communicating with their instructor, however, there were logistical issues when using it together with the free whiteboard site provided by General Electric (Table 9). Although no one left any comments after the second think-aloud D2L survey, everyone agreed strongly that the Adobe Connect Pro software facilitates pen-tablet communication with their instructor and that they preferred it over the free GE site. Besides the software issues, the only problem that students seemed to have with the USB pen tablet was the initial learning curve (Table 10).

Student Comments after 1st Think-Aloud Session
"Thought it was and will be a helpful tool for this class and others"
"It is a useful tool for a cheap price. I think a pen tablet pc works better, but is more expensive to fix if it breaks."
"All this is missing is a whiteboard site that all students have access to. Like something accessible through D2L"
"Everything was great about the pen tablets however, the only issue is staying connected between the instructor and student while in session."
"For this one it wasnt good that it kept disconnecting every so long. That was one of the drawbacks in that one."
"The session was cut off too soon, which could be a problem for long distance communications."

Table 9. Student comments after the first think-aloud session using a pen tablet, a telephone, and a free whiteboard site (www.imaginationcubed.com)

End of the Semester Student Comments and Suggestions about Pen Tablet Usage
"Learning/Adapting to writing style"
"The software student's had to use cut off too soon; the learning curve was a little bit high on getting used to using the pen tablet"
"The free GE website has a small pad/area to write on"
"Liked the Adobe Connect Pro better than the GE site. Adobe was alot easier."
"I found nothing wrong with the pen tablets. They were easy to use and install in the comp. The first tablet site wasn't that good because of disconnect the second was a great improvement"
"New software available for students to use to communicate with fellow students"
"There is a learning curve. You have to get used to the sensitivity of the device, much like you would a mouse"
"If there was a site all students could access through D2L for pen tablet communications (like the whiteboard sites we used), it would greatly facilitate the use of pen tablets between students, instructors, and campuses."

Table 10. Student comments about problems with pen tablet use and suggestions for future use (End of semester survey)

Conclusions

In response to my initial SoTL questions, the relatively inexpensive USB pen tablets together with the appropriate software were found to improve the access of the place-bound students to assistance from instructors; however, the pen tablets, like office hours, were still underutilized. One factor that may have contributed to this underutilization was that the University system attempted a software migration during the fall semester causing computer issues and putting students behind on some projects by about a week. Another was that several of the students were overloaded this semester between their work, family, and course load. Initial analysis of the learning-style survey data was not conclusive.

Although this pilot study was quite limited, it did demonstrate the potential for improved student learning (Tables 2 and 3). It also demonstrated that one to one think-aloud sessions may provide a means for improving student learning, not only for distance students, but for face to face students as well. As a result, an expanded use of these think-aloud sessions is being considered for future offerings. Overall, the students did see value in the use of pen tablets for distance offerings and suggested that they be retained for that purpose.

The above pilot study, completed in the fall of 2009, is being repeated. The Spring 2010 offering of Circuit Modeling I, a lower-division electrical engineering course, is being used for this second study. Unlike the fall offering of the course, this class is hybrid: being offered both live and asynchronously via streaming video. This second pilot offering should provide additional information about using pen-tablets and think-aloud sessions with distance students.

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