

Full Paper: Integrating the iPad Into the Engineering Classroom (Resubmission)

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Abstract

Beginning in 2016, Norwich University (NU) embarked on the Digital Citizen Initiative with the goal of including an Apple iPad as standard issue for all students and faculty. From 2016 to 2019, pilot programs were conducted to test the use of the iPad in both classroom and laboratory settings. In the Fall of 2019, all incoming first-year students at NU were issued an iPad along with an Apple Pencil. The authors performed a pilot study on the use of the iPad in multiple ECE courses, including circuits and electronics. Initially, the iPads were used to perform homework digitally, allowing for easy integration with the university's Moodle learning management system (LMS). Based on the results of this pilot, the use of the iPad has been expanded to other courses and applications including circuit simulation, hand sketching, and digital laboratory notebooks. The authors have also used the iPad for assignment grading, allowing for improved feedback, modernized grading workflows, and efficient LMS integration.

Introduction

One-to-one (1:1) technology programs are becoming more prevalent in P-12 environments. In terms of computing devices in education, 1:1 refers to an operational setup where each learner has a digital device. Frequently, 1:1 means each learner in a particular course has access to digital devices that are configured identically. The method of device issue and the selection of the device varies, with the most common options including laptops, iPads, or Chromebooks. In an article from 2017 [1], it was reported that more than 50% of K-12 teachers work in a 1:1 classroom environment, marking an increase from the approximately 40% rate reported a year earlier. A meta-analysis of 15 years of research studies [2] reports how 1:1 programs had a "statistically significant positive impact on student test scores in English/language arts, writing, math, and science." The same analysis [2] noted that many studies related anecdotal evidence of improved student engagement and persistence along with increased use of student-centered pedagogies in 1:1 classrooms. The prevalence and growth of these programs provides insight as to why the authors have noted that some of today's incoming students express being unpleasantly surprised by the lack of technology or the low level of technology in many higher-ed classrooms.

As today's students matriculate to college, they expect a technology-rich learning environment that is an improvement from what they experienced in their primary and secondary education. Mobile computing has become more commonplace in many industry and professional settings. As we work to educate future professionals, we should work to make sure the on-campus experience is preparing students for life after the university. It is important that instructors understand the challenges and opportunities related to 1:1 computing and mobile computing in the higher-ed classroom so they can attune their courses to the expectations and past experiences of their "natively" digital students. Since the release of the iPad, its use and suitability for the engineering and first-year engineering classroom has been studied with results disseminated through ASEE conferences. In 2012, it was reported [3] that use of the iPad in an introductory engineering course had positive impacts on the learning environment and the perceived learning impact from using the device; it was also reported that students in the iPad section maintained an academic performance on par with students in traditional sections. In 2013, at a different

institution, it was found [4] that students reported high expectations and a high desire to use iPads in engineering courses, and after one semester of use, students reported a decrease in the perceived academic benefits of the iPad and a decreased interest in their continued use.

Over multiple generations of the iPad, improvements to the file management system combined with the introduction of the Apple Pencil have resulted in a more powerful mobile productivity platform with increased potential utility in student learning workflows. In a more recent study of student iPad use in an FYE lecture and laboratory course at a large state university [5], it was reported that usage of the iPad device was high outside of the classroom, moderate to high inside the classroom, and lowest in the laboratory setting. In the same study, students reported using the device to enhance collaboration and communication inside and outside the classroom, including an enhancement of in-class discussion owing to the ready access to information. In a study of student perceptions of online learning tools and environments, Armstrong [6] advises that the perceived value of a technology depends less on the actual technology and more on how it is used, and how it is integrated into the class. He also found that without appropriate support, students will resort to less-academic tools and resources out of familiarity.

Given the prevalence of 1:1 device programs in P-12 education and our collective familiarity with mobile devices, the authors endeavored to explore and better understand opportunities for use of the iPad by engineering students, in and outside of the classroom setting. The remaining sections of this paper will detail the ways in which the iPad was incorporated into three different engineering courses at Norwich. A qualitative discussion including anecdotal observations from the instructors, student feedback, and example student work products will be shared. A quantitative analysis of student perception data collected through multiple surveys will be presented. A discussion of the experience and conclusions from the effort will be drawn.

Project Approach

Before iPads were issued to the entire campus, use of the iPad was piloted with cohorts from a variety of disciplines and a cross-section of the campus community. The authors volunteered to pilot the devices with 2nd year ECE students in the Circuits 2 and Electronics 1 courses. The authors worked to secure and distribute copies of the notetaking app GoodNotes. This app has multiple benefits including support for importing a template (such as engineering paper) and exporting work as a PDF while maintaining the background (template) image. Instructors modeled the use of GoodNotes while some students preferred other notetaking apps such as Notability and OneNote. While Electronics 1 had an associated lab, the focus of the pilot was on traditional classroom use of the device. Although the students were welcome to use the device in all their courses including their EE lab, no special attention was given to the platform. In Circuits 2, the textbook and homework systems used were digital—the McGraw Hill Connect platform. The iPad device was primarily used for notetaking, in-class problem solving sessions, and in-class think-pair-share (TPS) exercises. The instructor used the iPad for presentation to the students daily. Although the room was equipped with the technology to allow any user to wirelessly project their iPad to the screen in the room, that modality and switching of presenters was not that useful. The students having the devices and having digital documents with circuit schematics and other exercises for in-class use was very helpful and, anecdotally, it increased student engagement during in-class problem-solving and TPS exercises. We “flipped” the classroom from “chalk and talk” to “think and ink.” From the instructor perspective, having the

devices was particularly helpful for a unit that was graphing intensive. Having access to digital graphing templates along with a semi-infinite color palette and a notebook software that cleaned up lines drawn by students improved the quality of the students' work, reduced the time required to produce something of sufficient quality, and made it easier to focus on the learning objectives related to the bode plots.

In Electronics 1, the students had a traditional textbook and homework was submitted as a PDF through the LMS. Most students used the iPad to digitally prepare their homework, submitting PDFs of their digitally inked homework instead of meeting the requirement more traditionally—handwriting the work on paper, scanning it with a copier or mobile device (with an app such as Microsoft Lens), converting to PDF, and uploading. The instructional method for this course was a traditional “chalk and talk.”

One of the learning objectives of the introductory engineering courses at NU is to develop proper laboratory notebook techniques. Prior to the implementation of the iPad, students purchased bound, grid-style notebooks to use throughout the first-year intro to engineering sequence. Students used the iPad to collect data during lab and exported/submitted their laboratory notebook work via the LMS for assessment. In addition to lab notebook use, many students used the device to perform homework assignments. The engineering paper template proved useful to promote good homework habits.

At the end of multiple semesters, the authors issued an anonymous survey via the LMS to elicit feedback on the use of the iPad in various courses, ranging from first-year introductory courses to 2nd year courses in circuits and electronics. The survey included free response questions as well as questions utilizing a numerical scale.

Results and Discussion

In addition to the student feedback offered through a survey, the instructors evaluated student submitted coursework spanning the evaluation period. Shown in Figure 1 is student work from a homework assignment in a 2nd year electronics course. Note in particular the use of multi-color highlighting to keep track of similar terms as well as the shaded box to indicate the final answer(s). The use of the straight-line tool was also used effectively to divide the workspace in multiple regions.

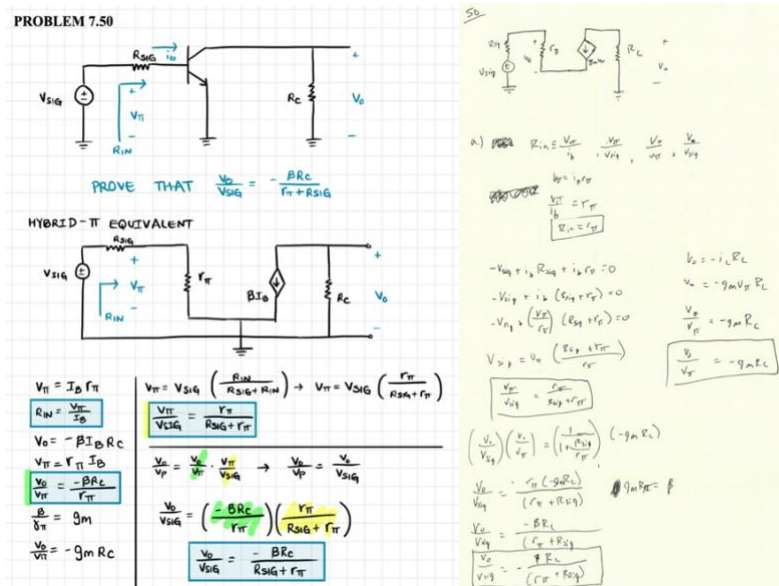


Figure 1: Analysis involving detailed mathematics and schematics from 2nd year electronics course. Work from iPad is shown on the left, while hand-written work is shown on the right.

The work shown in Figure 2 is an example of the use of GoodNotes for a laboratory notebook in an ECE-specific introduction to engineering course. In this example, the students utilized the iPad's built-in camera to capture photos of the circuit assemblies as well as a screen capture of the output of an oscilloscope. The student performed calculations based on oscilloscope data. Shown on the right is an example of a student utilizing the mark-up feature to highlight different circuit modules to aid in the construction of the full circuit.

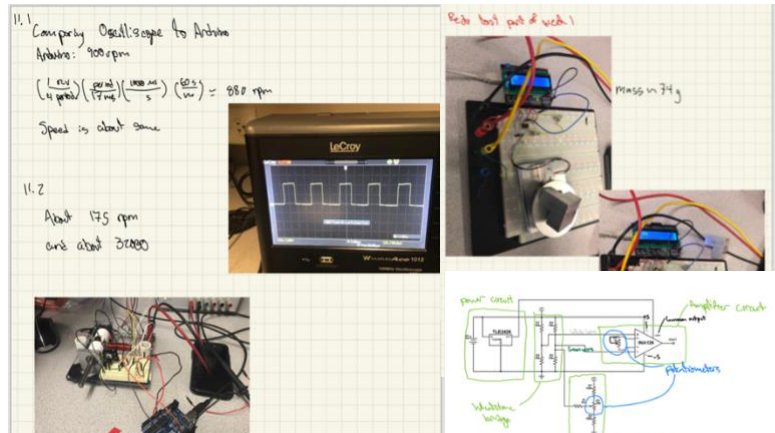


Figure 2: Demonstration of capability to embed data into notebook using the camera. Also shown is the use of mark-up to understand tasks to be performed.

Figure 3 represents an example of a laboratory notebook from an introductory to engineering course. In this example, students explored product development using a decision matrix and sketching skills to convey design details. Note the use of typing in the digital notebook example as well as the use of multiple colors in the bottom left image to emphasize details of the design.

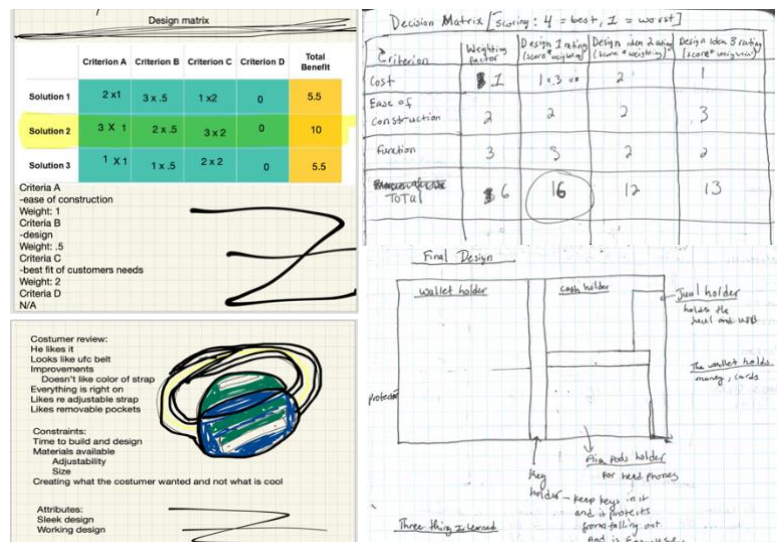


Figure 3: Digital lab notebook (left) and traditional notebook (right) used in design / prototyping lab. Use of color, improved legibility, creating tables and drawing not an obstacle.

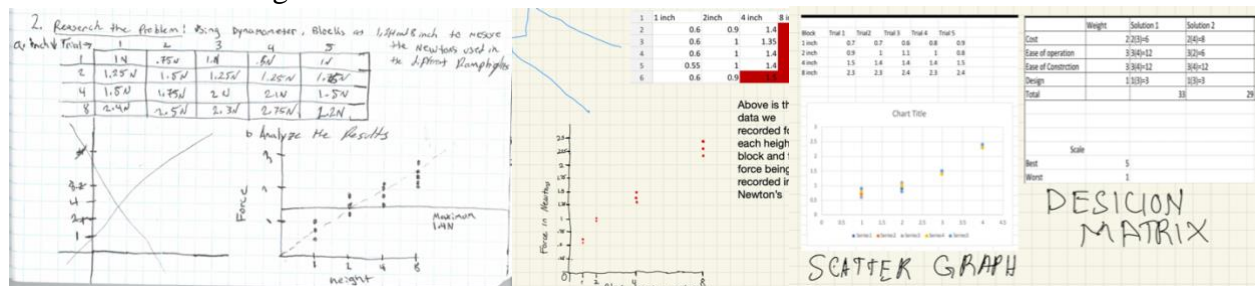


Figure 4: Progression of data collection / analysis with various levels of software augmentation. Left image is hand-written work while center and right images show work done using the iPad.

notebook with embedded Excel-generated data table and hand-drawn plot to digital notebook with embedded Excel-generated data table and an Excel-generated plot.

Students were asked free-response type questions. Some notable examples are shown below.

1. Would you like to continue the use of iPad in future ECE courses? Why or why not?
 - “Yes, it has all of my notes on it and I don’t see myself going back to paper notes anymore. This is super important to me because I always find my self going back to notes that I took from the other classes to catch myself up and better understand the new material.”
 - “YES! I really like using the iPad rather than carrying around different textbooks and notebooks and binders”
2. How have you integrated your iPad into your workflow for EG109? (Note taking, homework, reading, etc.)
 - “Absolutely, the Goodnote software is extremely useful in all my classes especially in engineering. Having to draw structures and plans has never been simpler on the ipad. I keep all my notes in Goodnote and barely use paper anymore and it makes college like 100x easier and more portable.”
 - “Yes, I primarily use it as a replacement for paper saving me time and increasing my organization for homework and note-taking.”

A summary of survey results from four semesters is shown in Table 1. This data represents both the pilot evaluation as well as the full-scale implementation. Since data was collected from the spring 2019 through spring 2021 semesters, the method of delivery included in-person (IP), hybrid (H), and completely remote (R) formats. The survey questions utilized a numerical scale of 1-5 where 1 = Strongly Disagree/Never/Rarely and 5 = Strongly Agree/Daily/Often.

Table 1: Course survey results based on 18, 16, 57, and 14 responses, respectively.

Question Summary	EE356/357 (S19, IP)		EG110A (S20, IP→R)		EG109 (F20, H)		EG109 (S21, R)	
	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ	\bar{x}	σ
iOS ecosystem is familiar.	78%		81%		84%		100%	
I use iPad for homework.	3.83	1.34	4.31	1.40	4.56	0.82	4.36	0.92
I use iPad for lab.	3.50	1.62	4.44	1.26	4.56	0.82	4.50	0.80
I use iPad for lab reports.	3.00	1.33	2.19	1.42	3.63	1.42	3.17	1.40
iPad improved my workflow in this class.	3.67	1.31	3.63	0.96	4.06	0.98	4.08	1.02
iPad improved my workflow in other classes.	3.56	1.44	3.46	1.20	4.15	1.00	4.00	1.10
Advantage to using iPad in lecture-style courses.	3.89	1.13	3.94	1.24	3.98	1.08	4.25	0.87
Advantage using iPad in problem solving courses.	4.11	0.96	4.44	0.63	4.18	0.98	4.50	0.67
Advantage to using iPad in lab-style courses.	3.78	1.56	4.44	0.81	4.37	0.96	4.50	0.67

The data shown in Table 1 indicates an overall trend of increasing average response over the duration of the evaluation from spring 2019 to spring 2021 semesters. Student familiarity with

the Apple iOS ecosystem increased from 78% to 100% over the period of this study. During this time, the use of the iPad in the classroom at Norwich has gone from pilot to widescale rollout / adoption. However, it is worth noting that the students surveyed in AY20-21 were first-year university students, so the increasing trends are not due to student familiarity from previous exposure / participation in the iPad rollout. The students commented that they enjoy using the iPad during lab to record data / notes as well as file management (combining files for submission of a single PDF file in the LMS), however satisfaction using the iPad to write lab reports has remained the lowest response. The lack of school-issued keyboard (although students are encouraged to purchase a keyboard) likely contributes to this. Overall, the number of negative comments was inconsiderable. A very small number of students commented that they preferred to take notes on paper. The use of a notetaking app was not required but was encouraged. Only one student surveyed expressed concern pertaining to the cost benefit perception of the device.

One repeated student response involved the benefit of using the iPad to replace notebooks and textbooks, reducing the need to transport multiple notebooks and textbooks throughout the day. Students also mentioned that they now have immediate access to textbooks / references both during class and while working on homework. An important outcome from this evaluation was the self-observed (and instructor-verified) improvement in organizational skill by many students. This program has also benefited the instructors of the courses. Collecting, evaluating, and returning laboratory notebooks was far less burdensome (physically and timewise). The instructors noted that the scope of content covered in the courses and complexity of assignments remained the same, and the increased interaction afforded by the iPad did not prevent material from being covered. The instructors also noted that student engagement in in-class think-pair-share exercises was higher while using the iPad.

This paper detailed the results of a multi-year evaluation of the use of an iPad in four engineering courses. Instructor support and modeling of the use of the iPad as a tool for engineering was critical in the overall success of the effort. Opportunities to further integrate the iPad into the curriculum are currently being pursued, such as the use of the iPad to aid in visualization / drawing skills. Ultimately, participating students and the instructors saw the iPad as a value-adding tool for the engineering classroom.

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