Using Technology to Reinvent a Learning Environment

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Using Technology to Reinvent a Learning Environment

Abstract:

This is a reflection describing the process of redesigning a lower division electrical engineering technology course at a large, public university. It describes the incorporation of active learning in the classroom, primarily through the use of LON-CAPA (Learning Online Network with Computer-Assisted Personalized Approach), a powerful open-source courseware system. In this electrical engineering technology course, LON-CAPA is used as a content delivery method to better organize diverse learning options for students. It is also a powerful tool that provides instant feedback to students and collects analytics to inform teaching to immediately address misconceptions. This tool provides dynamic questions that virtually eliminate cheating and allow for unlimited practice. The resulting course redesign, which is still evolving, creates a more student-centered environment that encourages students to access information that best supports their learning needs and focuses on the *process* of learning over the product. Even though there is a positive trend in student ability to solve course problems, the authors have encountered implementation challenges such as ADA compliance issues and limited content access to students outside the university, both of which are discussed in the paper as well.

1. Background

1.1 Course Redesign Goals

The general course format, which consists of two lectures and a two-hour lab each week, was initially developed by a team of faculty members from the School of Engineering Technology and was offered in the spring of 2012. The professor coauthoring this paper taught the second offering of the new course in the fall of 2012. Course challenges prior to the redesign included the following:

- The instructor was unable to grade all homework assignments due to time constraints and the number of students. Homework was spot-checked, and students did not receive feedback on all work.
- The turnaround time to grade and return homework provided opportunities for student misconceptions to become ingrained.
- Hand-grading homework provided an opportunity for human error and inconsistency.
- Homework problems were the same for everyone, which provided an opportunity for students to copy work instead of solving problems themselves.
- Time and effort spent grading homework reduced the time the instructor had to address individual needs and improve overall instruction.

To address these challenges, initial course redesign goals included:

- developing methods to automate grading to provide consistency, immediate feedback, and additional time for faculty to improve instruction and
- providing a more student-centered environment that would encourage student interaction.

1.2 The IMPACT Program Provides Assistance for Redesign Goals

In the fall of 2013, the professor participated in the IMPACT (Instruction Matters: Purdue Academic Course Transformation) program. The IMPACT program promotes a student-centered learning environment primarily based on the Self-Determination Theory, which suggests that a more student-centered environment can be created by addressing student needs for autonomy, competence, and relatedness (Deci & Ryan, 1985). The program encourages faculty fellows to consider Chickering and Gamson's (1991) seven principles for good practice in undergraduate education as they redesign their courses:

1. Encourages student-faculty contact.
2. Encourages cooperation among students.
3. Encourages active learning.
4. Gives prompt feedback.
5. Emphasizes time on task.
6. Communicates high expectations.
7. Respects diverse talents and ways of learning.

Throughout the 13-week course redesign process, the instructor reflected on how to incorporate research-based methods into this course to accommodate student needs. He critically evaluated his course learning outcomes, developed objectives to support those outcomes, and determined how to assess the results to ensure student understanding.

2. Evolution of Course Content Delivery

After redesigning his course outcomes and objectives, the instructor decided to create his own eText in order to focus reading content and ensure that the course material would meet his learning outcomes in a way that matched his teaching style. He also was able to significantly reduce student course material costs.

2.1 Initial eTexts

Initial versions of the course eText consisted of clickable links to PDF chapter files hosted by Skyepack. A revised version looked identical but consisted of clickable links to streamed web content separated by chapter (see Figure 1). These versions were not ideal for multiple reasons:

- The PDF documents were not always consistently searchable.
- The professor was not able to integrate video demonstrations within the text.
- Students had to read content in one platform and then switch to another platform to complete homework exercises.
- The professor was not able to separate the chapter text into targeted topic sections within a chapter.

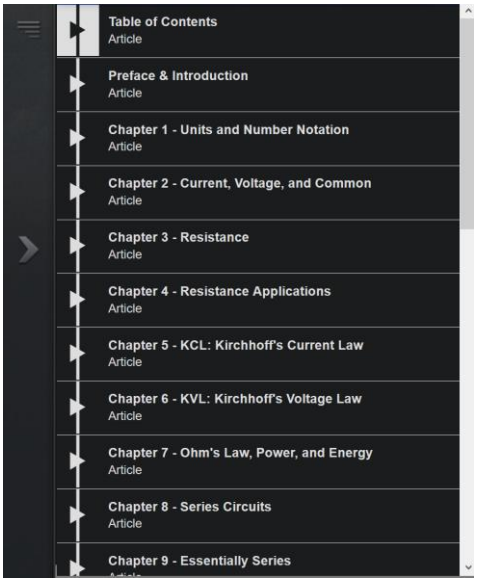

Figure 1. Image of initial eText information hosted on Skyepack. Each section linked to a specific chapter.

2.2 Integrating a Free and Powerful Homework System

As part of the course redesign, the professor enhanced his use of LON-CAPA (Learning Online Network with Computer-Assisted Personalized Approach) for practice and assessment. LON-CAPA is an open-source learning content management system developed by Michigan State University and supported by an NSF grant. This powerful system allows instructors to develop and share basic problem formats that will automatically generate randomized variables for each student in order to create different versions of the same problem (i.e., dynamic problems). This feature allows the professor to use the same basic problem for homework as well as formal assessments, ensuring alignment between course activities and assessments. Instructors can provide hints for missed questions, and students can be given additional opportunities to solve the problem once misconceptions are addressed (see Figure 2). By creating varying versions of the same problem, students are able to practice unlimited problems until mastery is achieved. Dynamic problems also virtually eliminate cheating by encouraging students to talk through the problem-solving process rather than sharing answers.

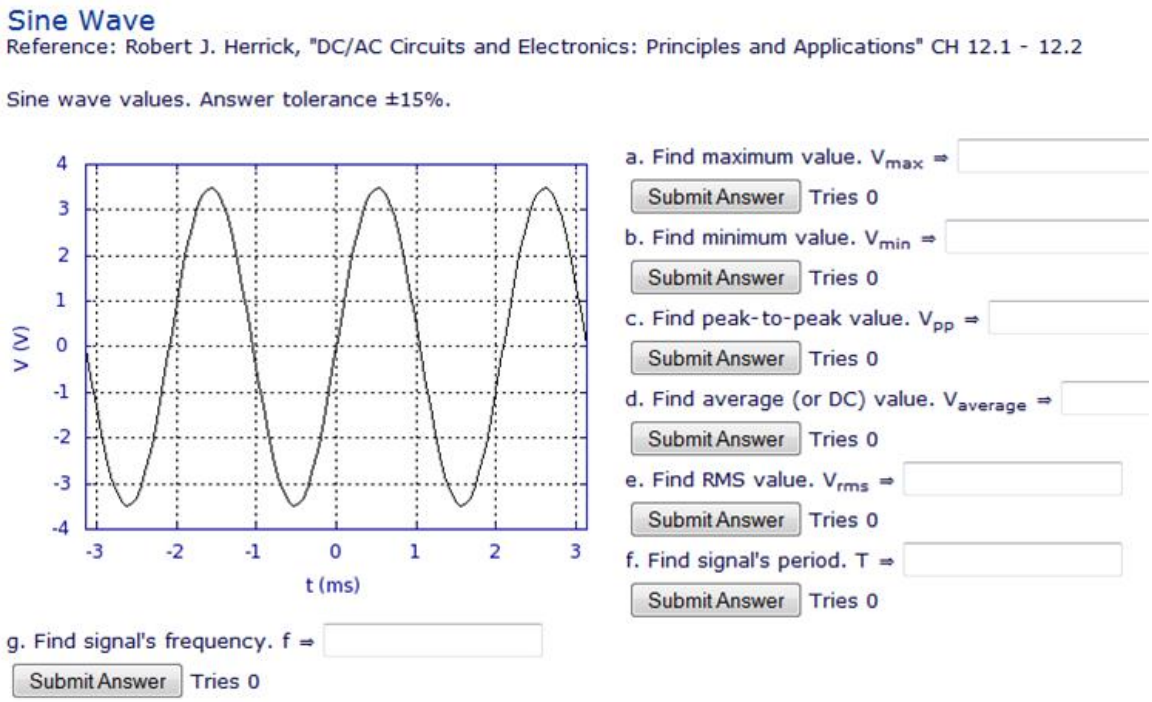

Figure 2. Dynamic sine wave problem. Each student receives a variation of this problem with a different graph to interpret.

2.3 Creating Active Learning and Encouraging Teamwork

Through the use of LON-CAPA's dynamic questioning function, the professor was able to create an element of gaming to the classroom and reinvent the face-to-face learning experience. In lecture, five to nine students sit together in teams at their own tables with one vertical display monitor per table. One student at each table connects to the vertical monitor to display a problem to solve that typically involves schematics and several complex problem parts. Each student in the class has his or her unique parameters but is solving the same problem together as a team. The vertical display is critical so that everyone at the table has the same viewpoint of the visual being displayed for team discussions. Having teams of students work through these complex problems during class creates an element of gaming and healthy competition. Each student's submitted LON-CAPA answer is immediately evaluated to be right or wrong; three attempts are allowed and the correct answer displayed. Additionally, there is a copy of all the problems in a practice folder where the students may attempt a problem as many times as they wish without any grade recording. The professor is able to take advantage of LON-CAPA's integrated system with Blackboard to automatically upload LON-CAPA results into Blackboard, which occurs automatically overnight without any manual intervention.

2.4 Using Data to Inform Instruction

In addition to randomizing variables within a problem, answer choices and question order can also be randomized, making cheating extremely difficult, even when students sit next to each other in a computer lab. When questions are randomized, LON-CAPA can provide analytics on each question to provide instructor feedback on misconceptions and question difficulty. The

professor is also able to use this as a formative assessment tool to help guide his class discussion based on these particular students' misconceptions during in-class quizzes and homework problems, and use class time more effectively. This process, known as *just-in-time teaching*, encourages students to become more actively invested in their own learning (Novak, Patterson, Gavrin, & Christian, 1999). (For specific information on the various analytics available using LON-CAPA, please refer to Appendix A.)

2.5 Refining the Learning Environment to Increase Student Time on Task

The reflective process of the IMPACT program encouraged the professor to refine his learning materials to align to specific learning objectives. He revised his Skyepack eText to allow students to link directly to specific sections of a chapter. This revision allowed students to spend more time interacting with the content instead of navigating through it to find specific information (see Figure 3).

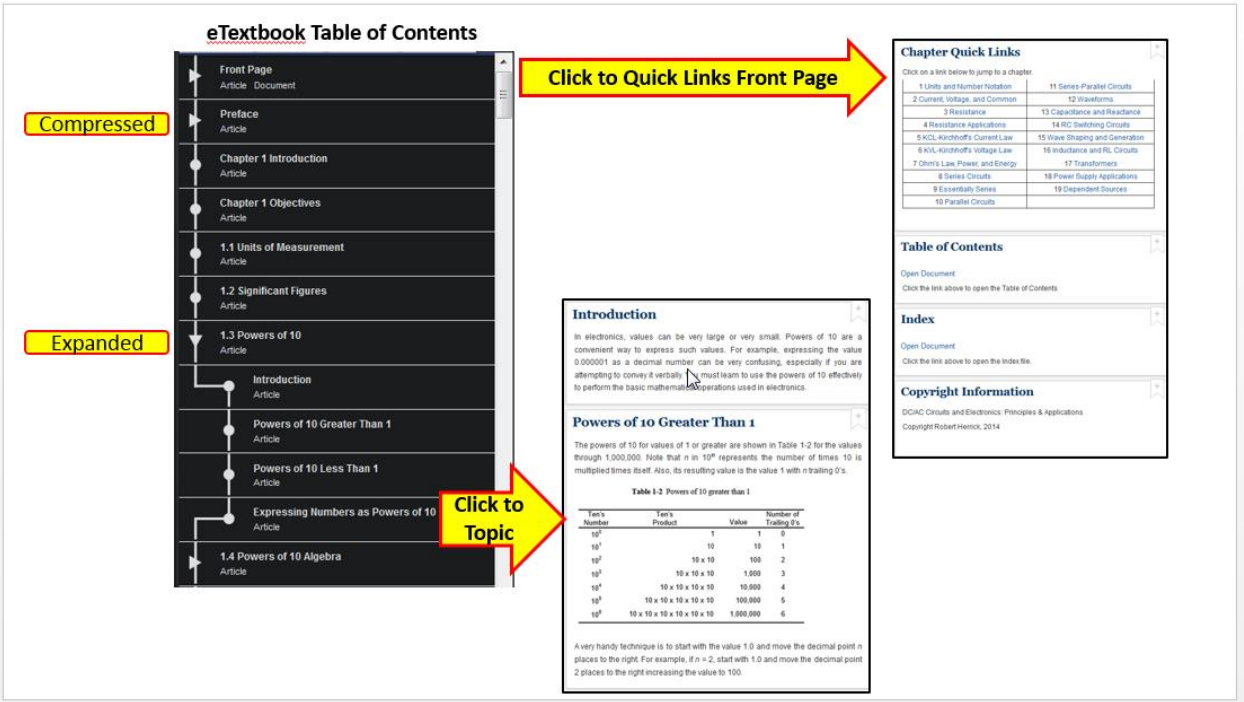

Figure 3. Image of Skyepack eText indicating how it links to targeted information within a chapter that addresses specific learning objectives.

He also began to replace full-class, recorded lectures with short video modules for more focused learning and easy access to the topics. By providing focused videos and content, he is able to increase student time on task.

2.6 Providing Multiple Learning Modalities

With a quality headset and action PowerPoints, the instructor creates video tutorials that demonstrate various processes to enhance learning retention. Incorporating targeted video content lectures as well as video demonstrations into the learning environment help to provide

multiple avenues for explaining concepts. He encourages student autonomy and competence by allowing students to review the videos as many times as necessary until they master the content. Providing captioning not only assists students with hearing impairments, but it also aids students whose primary language is not English. Increasing the speed of the video decreases the time spent, and students have indicated that increasing the speed of the video by 1.5 to 2 times generally does not affect comprehension.

These changes led to a flipped-classroom model that currently includes a very short "Hot Topics of the Day" introduction followed by team interactive learning of LON-CAPA homework problems, allowing students time in class to practice foundational as well as novel concepts, with peer support and immediate instructor feedback. This interactive classroom experience encourages students to (a) relate to each other as well as the content provided; (b) apply what they learn to real situations and experience a sense of progress, mastery, and success that is essential to learning (Zull, 2004); and (c) acknowledge and respect each other's diverse learning needs.

2.7 One-Click-Away Concept: Using LON-CAPA as an eText Platform

As the instructor began to incorporate more of these elements into his teaching, he realized that students were becoming frustrated at having to use multiple resources for text (Skyepack), videos (Blackboard), and homework (LON-CAPA). He decided to host all of his teaching materials through LON-CAPA, creating a new type of eText where all of the learning materials were only a single click away. He applied to the university's eText pilot in order to receive support for this major undertaking. The pilot provided financial and instructive support for the writing, editing, design, and distribution of the eText.

The instructor was accepted into the program because of his innovative approach to using LON-CAPA as both an eText platform and a powerful—and free—homework system. Since the math department was conducting a similar pilot, creating their own eTexts using LON-CAPA as a type of eText platform, the security and accessibility provisions had already been tested, and the eText pilot team was cleared to support the instructor with this project.

The eText redesign, using LON-CAPA as the eText platform, allows the instructor to house the numerous instructional resources for each topic (note the row of links indicated by the red arrow in Figure 4) in the same space as the corresponding LON-CAPA dynamic questions (indicated by the blue arrow in Figure 4).

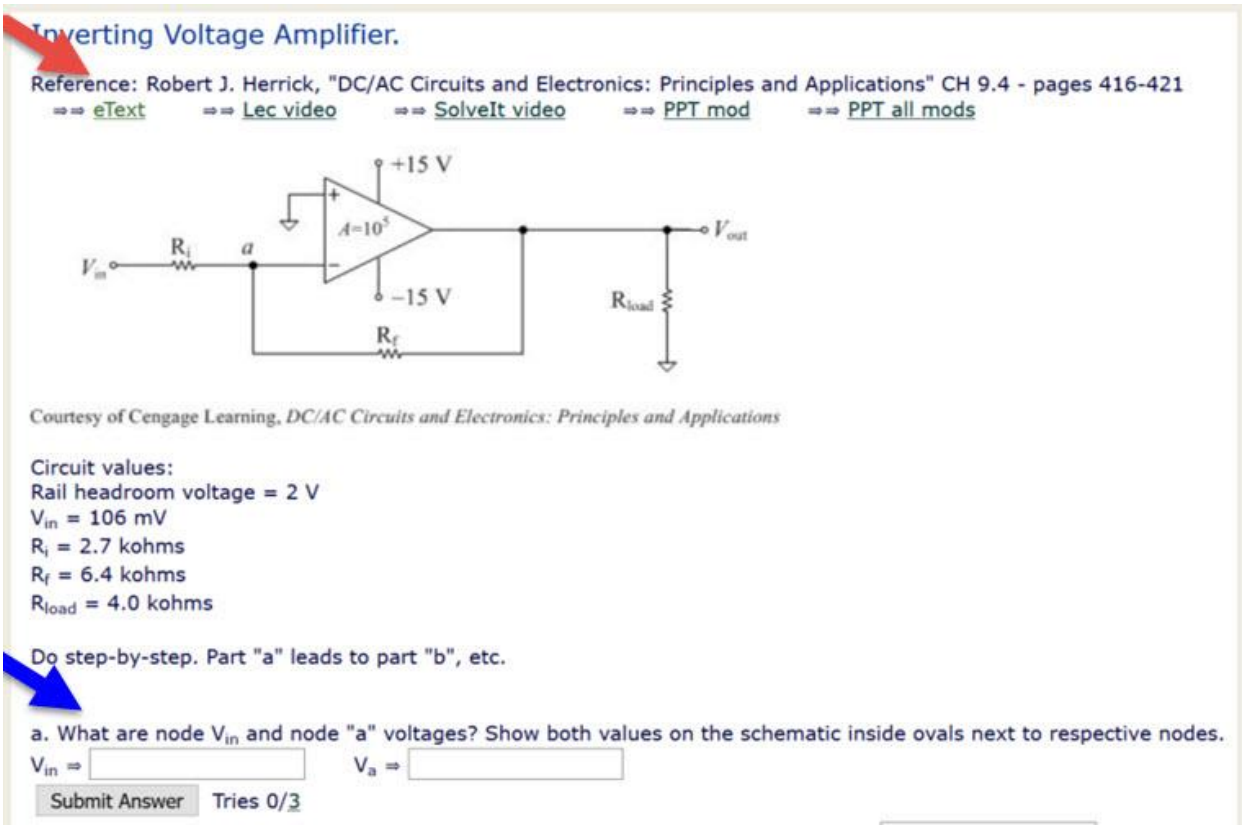

Figure 4. The instructor uses LON-CAPA as an eText platform to house targeted, static learning resources in one place (top red arrow) alongside a dynamic questioning tool (bottom blue arrow).

In this particular course the eText is still housed on Skyepack, but the course content is presented as a complete learning experience using LON-CAPA as a content delivery system. Static course content is housed alongside dynamic questions, which contain the same question format but offer randomized variables for each student. Student answers are graded automatically after clicking the submit button. There is an option to provide immediate feedback for incorrect answers, and the instructor sets the number of attempts allowed for each problem.

Figures 5 through 10 demonstrate the one-click access to relevant resources that are available to students while in the midst of solving a specific problem. Students can choose to go to the eText topic, watch a lecture video, review PowerPoint presentations, or view a SolveIt video, which provides just-in-time support for students as they attempt to solve the relevant problem. Organizing the material in this way allows students to work more efficiently and spend more time engaged in the content as opposed to being engaged in navigating the content.

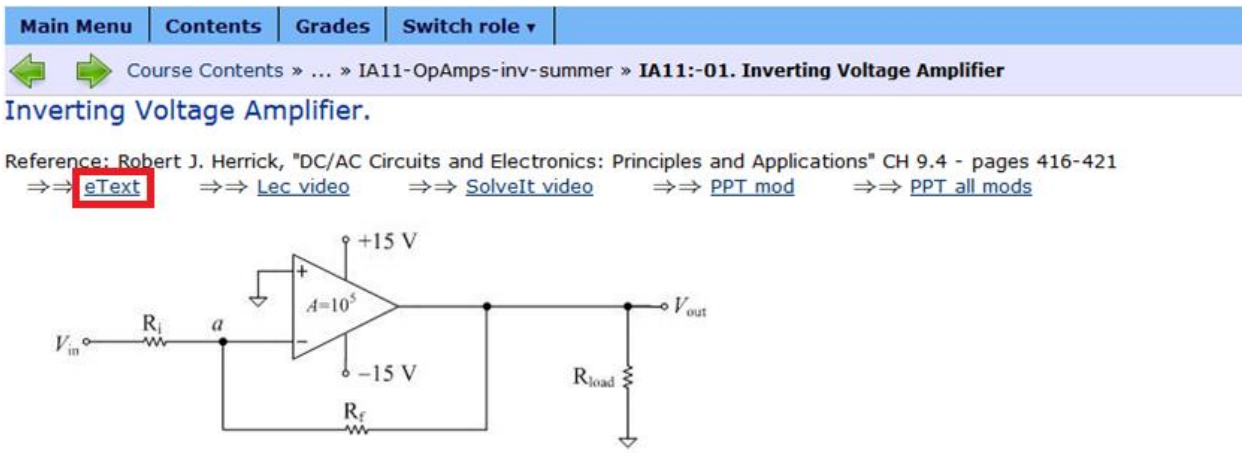

Figure 5. Link to the specific section of eText (housed on Skyepack) that deals directly with the material being presented (inverting voltage amplifier).

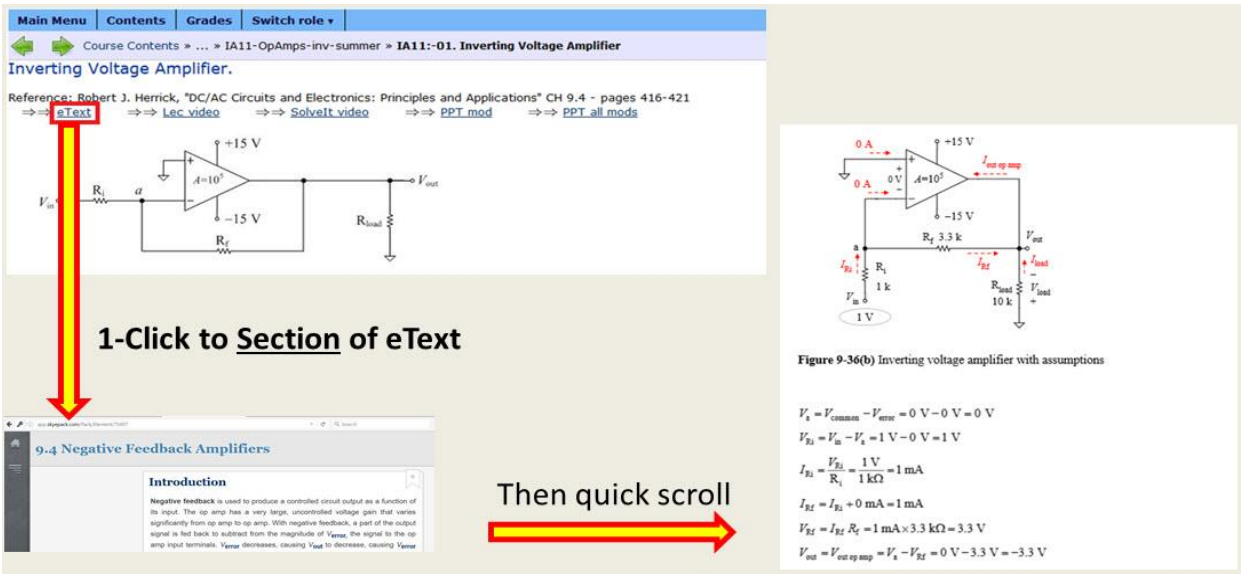

Figure 6. Demonstration of connection to the specific section of eText.

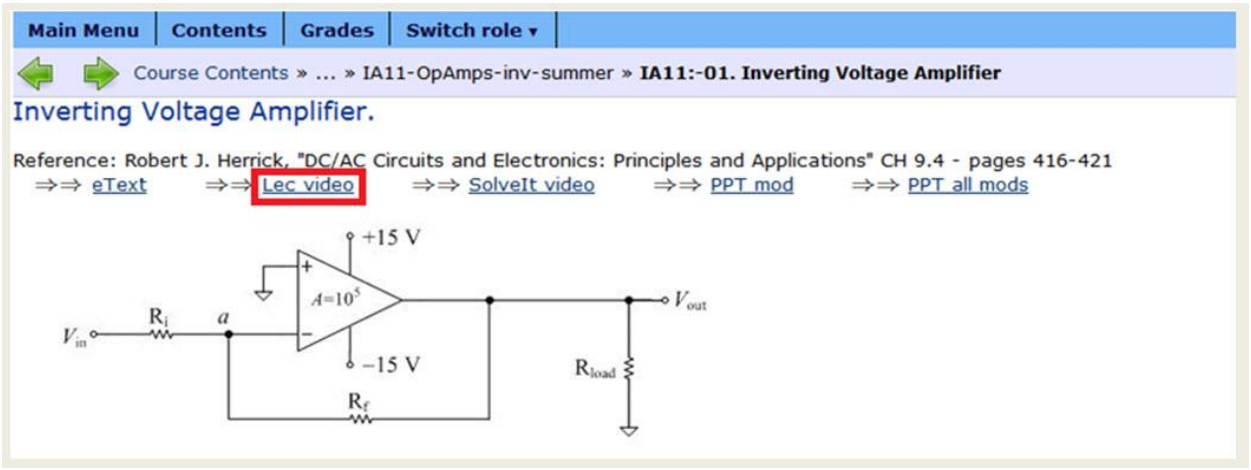

Figure 7. Captioned video with the ability to increase or decrease the speed.

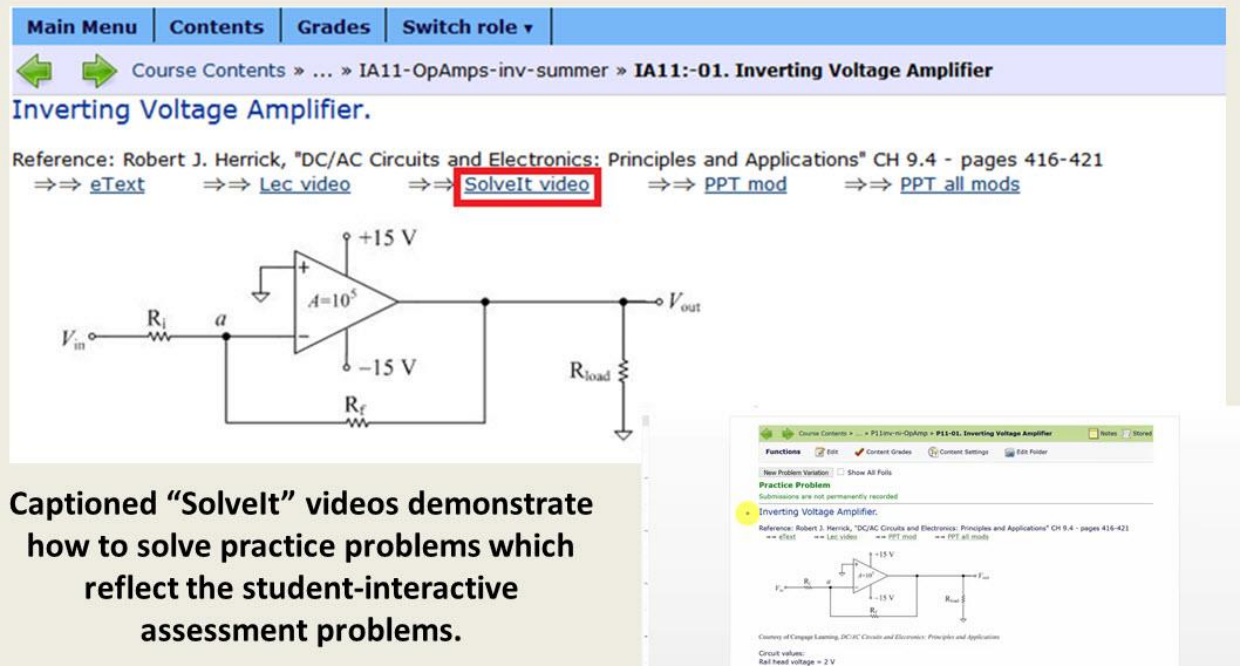

Figure 8. Depiction of links to the SolveIt video, which provides just-in-time support for students as they attempt to solve the relevant problem with the option to speed up or slow down the video.

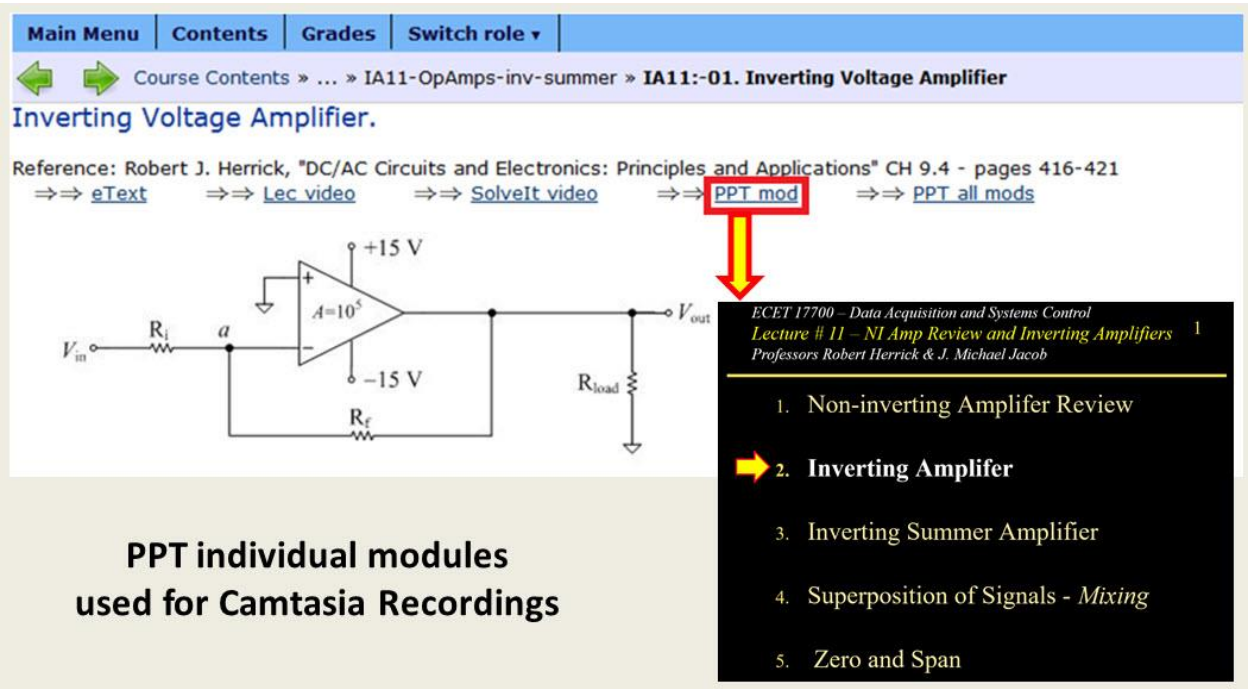

Figure 9. Demonstration of accessibility to the specific section of the lecture PowerPoint used to create the corresponding video module.

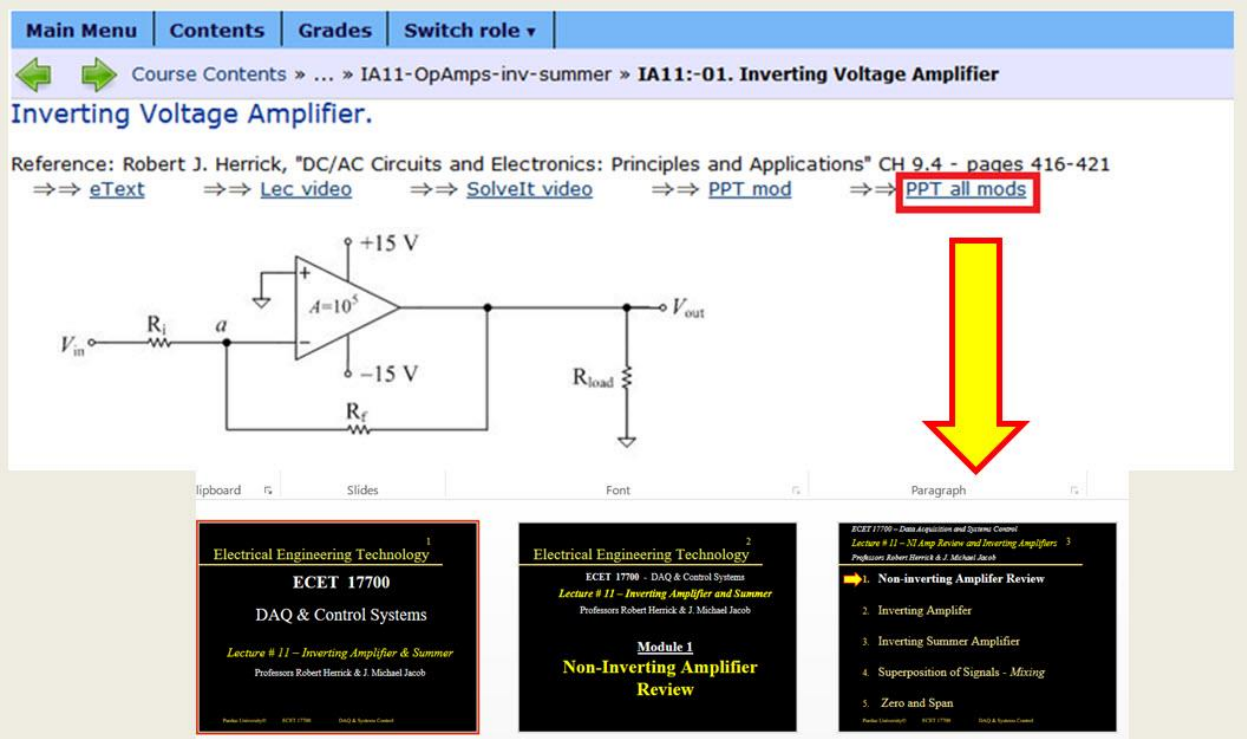

Figure 10. Links for the master PowerPoint that compiles all of the PPT modules for a specific lecture to deliver a broader context of how the specific material being presented connects to the bigger conceptual picture.

Even though the interface may not be as polished as a pay-per-use homework system, the flexibility, convenience, customization options, and cost savings for students makes this a good choice for many instructors using LON-CAPA as a type of eText platform. It offers many benefits and capabilities, such as:

- integration with MAXIMA CAS and the R project systems
- dynamic and static plots
- acceleration plots
- integration with Blackboard
- problem/activity/text collaboration among learning communities
- interactive assessment delivery
- fully customizable system
- immediate, formative feedback
- analytics to shape content delivery

For additional information, the LON-CAPA website (www.loncapa.org) provides a list of research papers associated with the use of LON-CAPA.

3. Considerations for Digital Media

3.1 ADA and UDL Considerations

During the process of developing the eText, the instructional designer worked with the professor to ensure that Universal Design for Learning (UDL) and Americans with Disabilities Act (ADA) requirements were met. Universal Design for Learning delivers a framework for providing a learning environment that supports multiple learning modalities, the different ways that students can express what they know, and the various ways that instructors can engage the learner (Cast, 2012). Allowing students to choose the way they prefer to learn also supports the Self-Determination Theory by providing students a sense of autonomy. With multiple attempts to solve a problem as well as immediate feedback, students gain confidence and competence.

It was important for both UDL and ADA that the videos were captioned. The ADA mandates that videos are made accessible for those with hearing impairments, which requires captioning. However, captioning benefits all learners. It provides an additional avenue for clarifying meaning and provides vocabulary for increased comprehension, especially for international students, but additionally for students with learning disabilities and students studying in noisy environments (Teal Center Staff, 2010). Having easy access to text and video of the same material allows for the presentation of information catering to multiple learning preferences as well as numerous opportunities to explain information to aid in retention. These attributes contribute to UDL (Cast, 2012).

The ADA requires that all online materials be accessible to those with visual impairments, which includes PowerPoint, PDF, and Word documents. The latest versions of these programs contain accessibility checkers to assist the user. While the team attempted to make all previously created PowerPoints accessible, this was an overwhelming task, especially for those PowerPoints that were made using older versions of the program that did not include an accessibility checker. With the number of videos that needed to be captioned, the instructor agreed to focus on those first and make any new material accessible as it was created, going back to make previous materials accessible as time allowed.

The team faced additional challenges as well that are particular to this field of study. For example, colors were used to distinguish current in circuits consistently throughout the text. Since using color to indicate meaning is not acceptable for ADA compliance due to color-blindness, additional features (such as dotted or thickened lines and lines with arrows) to indicate meaning were incorporated. It was difficult to provide alternative tags (mandated by the ADA) for certain illustrations within the PowerPoints because they indicated a process that was much better explained via image. This is an issue for all online educational materials that contain images that demonstrate a process.

3.2 Making Content Available to Others

LON-CAPA has a foundational mission to share content with other instructors, and this professor has set his problems to be open to the public with shared access to his original source code. However, he would also like to make most of his course content available to students outside of his current institution through eText. Unfortunately, this is one limitation he is still struggling to meet.

4. Evaluating Effectiveness of Course Redesign

4.1 Learning Experience

The eText initiative was part of an integrated effort by the professor to enhance the learning environment in a synergistic, holistic approach. Isolating any part for course introduction and assessment for its unique benefit as a controlled study was not his strategy.

4.2 Student Survey Results

Since this was a holistic jumpstart, and a controlled environment discernment of a single part cannot be determined, this professor developed a Qualtrics survey to assess the students' perception of their learning environment (see Figure 11). Every component of the transformation was viewed as "Effective" or "Very Effective" with a high percentage of the students. The only exception was the eText housed in Skyepack, which was rated at 25%, even though it was developed to take students to the specifically related content sections for a given problem. However, there may have been some confusion for the students about which resource (the Skyepack "eText" or the LON-CAPA platform that incorporated the Skyepack eText into a broader resource) constituted the actual eText. Clarification of terminology will be helpful for measuring effectiveness in future course iterations.

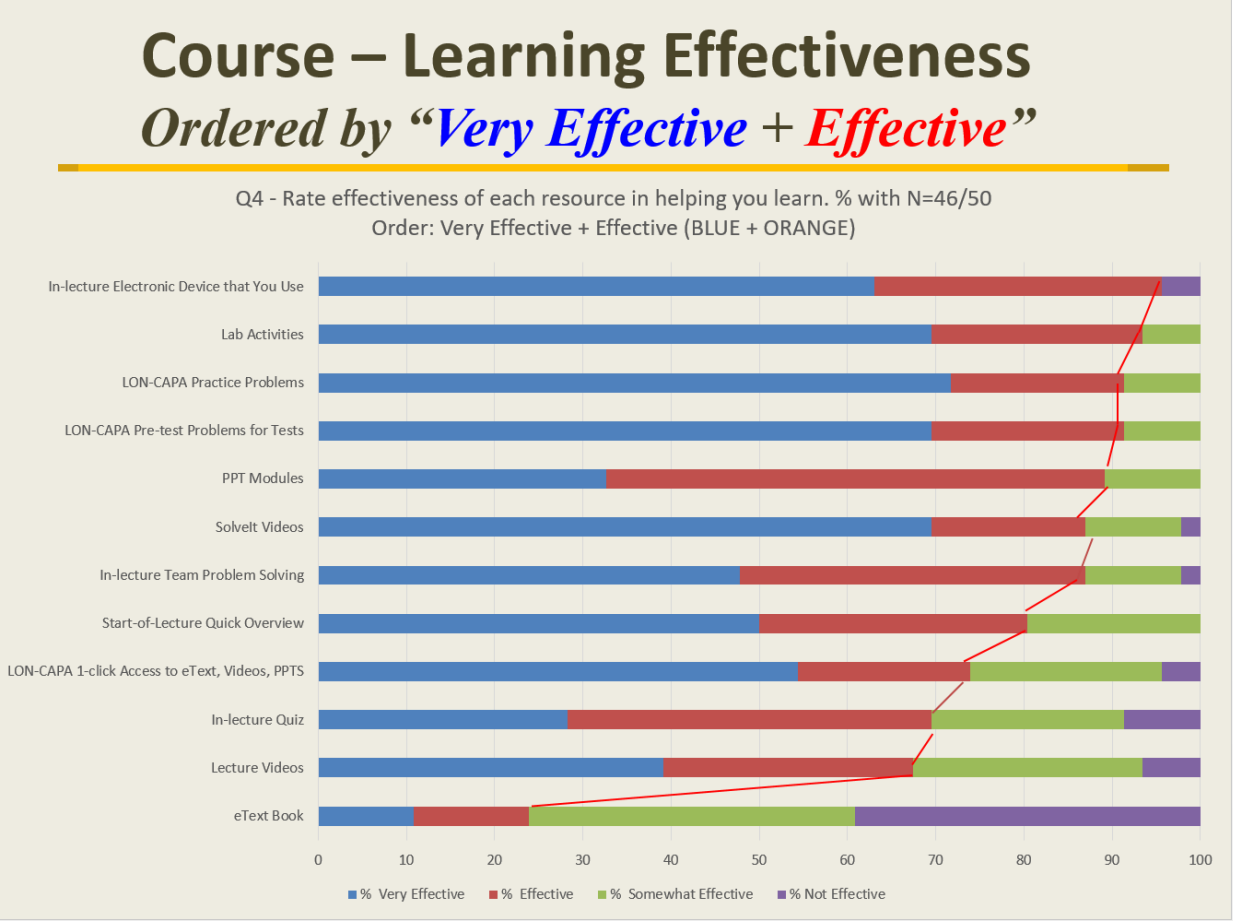

Figure 11. Bar graph depicting student perceptions of the effectiveness of various instructional strategies and resources implemented in the course.

Some observations about the survey data:

- Note that 60% of the students rated eText Book as somewhat to very effective.
- Although students rated the other methodologies as being more effective, a fair percentage of the students still need some form of textbook (either written or digital) to solve problems and study for exams.
- The eText housed on Skyepack is only directly applicable to 40% of the course (foundations of DC and AC circuit and electronics analysis), so it is not effectively useful for the remaining 60% of the class (data acquisition and systems control). It will be interesting to see if the perceived value of the eText rises with 100% use of this content throughout the semester.
- In general, students appear to want the minimum text material needed to solve a problem or pass an exam. In some applications this could be very helpful, but there is a longer-term strategy of understanding technology in context and framing it to a larger understanding. This professor plans to provide a balance between these two opposing but realistic goals as the course continues to evolve.

4.3 Anecdotal Data

Other anecdotal data and observations are used to assess the effectiveness of this holistic transformation. Note that these are informal comparisons, since the transformation was rapid and included all transformational elements concurrently, without strictly controlled, measured, progressive steps.

The professor's perception is that learning has improved to the point where he is incorporating more differential content into the course, and the students continue to perform at a higher level since the transformation. The class learning environment is now dynamic with all students participating at some level, some more than others, but still actively engaging in their own and their fellow students' learning. There is an electricity in the air as these groups dive into and solve problems together—the chatter level is high and effective. For some, this is a "fun" way to learn.

4.4 Upward Trend in Student Grades

A comparison of the before and after change in average and median course grades using Blackboard data can be seen below. It should be noted that the difficulty level of the assessments across different sections has been consistent, thus, it is interesting to note the upward trend in average and median course grades.

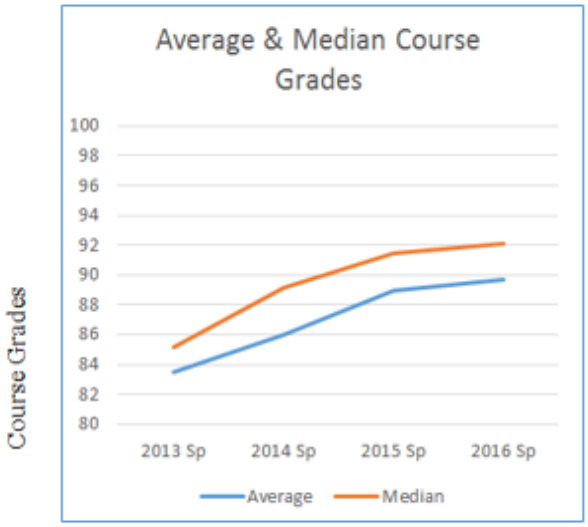

Figure 12. ECET 17700-Data Acquisition and Systems where majority of students are freshman and sophomores.

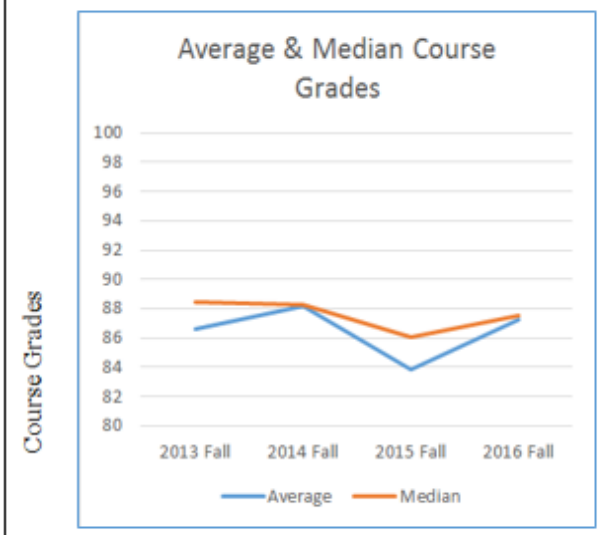

Figure 13. ECET 17700-Data Acquisition and Systems where majority of students are sophomores and juniors.

The data has been bifurcated according to student demographics to note an interesting trend. The trajectory of average and median course grades for students in the spring course iterations, which consist mainly of second semester freshmen on track with the plan of study, varies from the students in the fall iterations, which consist of mostly sophomores, followed by juniors, non-majors, and seniors. Although data for both groups seems to indicate an upward trend in achievement according to grades, it is curious that the spring course iterations show a more definitive growth pattern than the fall course iterations. This may warrant further investigation to ensure that different student needs are being addressed.

Conclusion

It is important to note that this data was not collected as part of a formal experiment, but instead was meant to formatively assess multiple changes being implemented concurrently in ECET 17700 so that the instructor could adjust his teaching strategies to better help his students. The changes being made were based on pedagogical principals such as Universal Design for Learning (UDL) and other student-centered approaches, including just-in-time learning and Chickering and Gamson's 7 Principles (1991), but it is impossible to isolate one variable to prove a causal relationship. It is also important to keep in mind that a classroom is not a perfectly controlled experimental environment. Instructors cannot randomize their subjects nor control the environment across course iterations (same classroom, same student demographics, same time of day, same student and professor life circumstances, same classroom size, same weather, etc.). There are also ethical dilemmas in attempting to create a control group of students who do not receive the same educational opportunities as others, who expect the same quality education, when it is obvious to an instructor that a pedagogical strategy is engaging more students and creating an exciting learning environment.

Redesigning a learning environment is a huge undertaking that should be approached with a mindset of making gradual changes over time. Implementing new technologies and pedagogical strategies involve a learning curve as both instructors and students adjust to the different strategies and deal with the inevitable hiccups that occur. Faculty need to find what works for them as well as their students.

The most important takeaway from this experience is that the key to a successful learning environment involves data analysis, reflection, and the willingness to be flexible enough to adapt the course to meet changing needs. It is important for faculty to have support to do this, and this instructor was fortunate to have this assistance through IMPACT as well as the eText pilot. The specific tools used to reach these course goals are relevant only to the ways in which they also meet the needs of the students and the instructor.

Using LON-CAPA allowed this instructor to meet his needs as well as the needs of his students in the following ways:

- The system allowed him to provide immediate feedback to students.
- The automation communicated high expectations because students knew that all of their work would be graded, not just random problems.
- The automated grading freed up time for the professor to devote to reflection, data analysis, and course redesign.
- The inclusion of all materials in one convenient spot encouraged student time on task.
- Having multiple learning materials respected diverse learning preferences and provided multiple ways to enforce learning.
- Providing more materials online freed up class time for more active learning and individualized attention from the instructor.
- The randomized problems coupled with the in-class activities promoted an active learning environment that encouraged student cooperation. Students began to focus on helping each other through the process of problem solving instead of simply sharing answers.

LON-CAPA is an open-source product with sophisticated and advanced features that can improve teaching and learning experiences. It is not necessarily the best option for everyone, but it may benefit instructors at other institutions as well. In fact, there are users all over the world, and there is a very strong support group that works to help resolve user questions and issues

The instructor has encountered challenges during this journey that still have not been completely resolved. For example, providing alt tags for an image that demonstrates a complicated process is difficult, but it must be addressed in order to achieve complete ADA compliance. The instructor would also like to find a place to host a different LON-CAPA instance in order to provide access to all the material contained in the eText outside of this university. The professor acknowledges that he has been fortunate to receive support from the university as well as strong support from the LON-CAPA community. He encourages future researchers and/or practitioners to contribute to identify potential solutions and become part of a larger community of learners.

Acknowledgement

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Appendix A: LON-CAPA Analytics

There are several analysis tools and data available for rapid detailed analysis of student assessment performance. What follows are a few examples of what is used by the professor to assess the effectiveness of the student LON-CAPA exercises and examinations.

A.1 Problem Part Difficulty Analysis

Upon entering LON-CAPA, the homepage (Figure 14) provides the following view of the course and difficulty listing of the problems based upon average attempts. For team class activity problems, each student is allowed up to three attempts; exams include two attempts. These analytics highlight the most difficult problems that can then be utilized by the faculty for follow-up.

(Problems with av. attempts ≥ 2 or deg. difficulty ≥ 0.5) and total number of students with submissions ≥ 2 Hide

Change thresholds?

Resource	Part	Num. students	Av. Attempts	Deg. Diff	Last Reset	Reset Count?
FinalExamLC:-10	part - b	50	1.58	0.52		☐
FinalExamLC:-11	part - b	50	1.60	0.64		☐
FinalExamLC:-12	part - b	50	1.58	0.58		☐
	part - d	50	1.50	0.53		☐

Figure 14. LON-CAPA indicates problem difficulty.

A.2 Test Item Analysis

Item analysis for an exam can be created very quickly for results by exporting a LON-CAPA spreadsheet (see Figure 15 for an example of a final product of this process). Each semester's hourly tests and final exam data is downloaded from LON-CAPA per student per part with the number of attempts-both successful and unsuccessful- into a spreadsheet. The data then is loaded into a prepared spreadsheet and translated into each problem part's success rate. The resulting far left columns display the summative data, which are shown graphically to the right. The table's color scheme highlights less successful results to make them more apparent and traceable over time. Once the original spreadsheet template is created, it takes about ten minutes to download and complete this spreadsheet for every part of every question on an exam. It is accurate and complete for a detailed item analysis for an evaluative continuous improvement process in a matter of minutes.

ECET 177 -- Test #2 - item analysis with flipped classroom

	Not Timed	Timed
N class #	**25**	**56**
Avg	**85.26**	**82.30**
Median	**91.43**	**85.71**
avg check	85.26	82.30

	Not Timed F14-T2	Timed S15-T2
1a. Thevenin: Eth	100	98
1b. Thevenin: Rth	88	82
1c. Thevenin Model Loaded	76	86
2a. Thevenin to Norton: RN	100	98
2b. Thevenin to Norton: IN	100	96
2c. Thevenin to Norton: Norton Model	88	88
3a. Op Amp Follower: feedback	92	88
3b. Op Amp Follower: Va	96	95
3c. Op Amp Follower: Vout	64	50
3d. Op Amp Follower: Av	96	96
4a. Nonlnv Amp: Va	96	100
4b. Nonlnv Amp: I_Rf	64	71
4c. Nonlnv Amp: V_Rf	84	89
4d. Nonlnv Amp: Vout	72	64
4e. Nonlnv Amp: Av	92	89
5a. Inv Amp: Va	68	80
5b. Inv Amp: I_Rf	60	61
5c. Inv Amp: V_Rf	80	88
5d. Inv Amp: Vout	56	54
6a. Summer: Vout_music	72	70
6b. Summer: Vout_tone	84	77
6c. Summer: Increase Music	100	88
6d. Summer: Rin_music Rin_tone	96	88
7. RC ckt: f increase effects	64	59
8. Capacitive Reactance	88	89
9a. RC Filter: Low Pass	100	100
9b. RC LP Filter: fc critical frequency	100	89
10a. Freq Response Curve: filter type LP	100	100

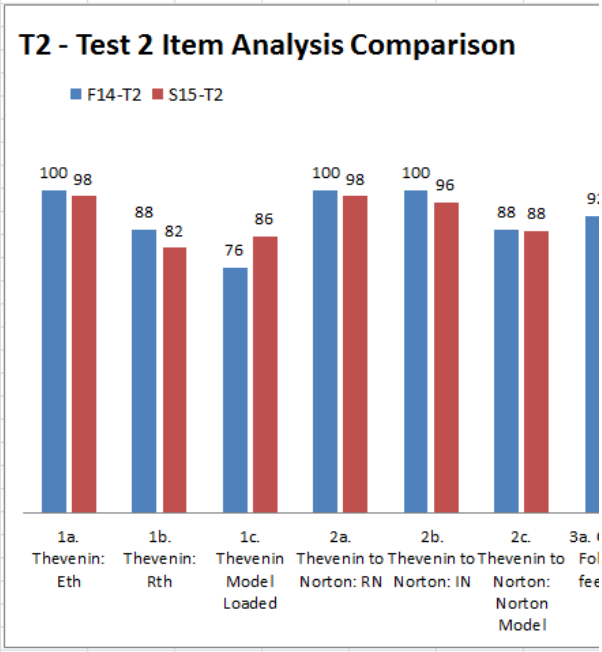

Figure 15. Example of a LON-CAPA test item analysis of every problem part.

Appendix B: Comparison of Student Demographics for Spring and Fall Course Iterations

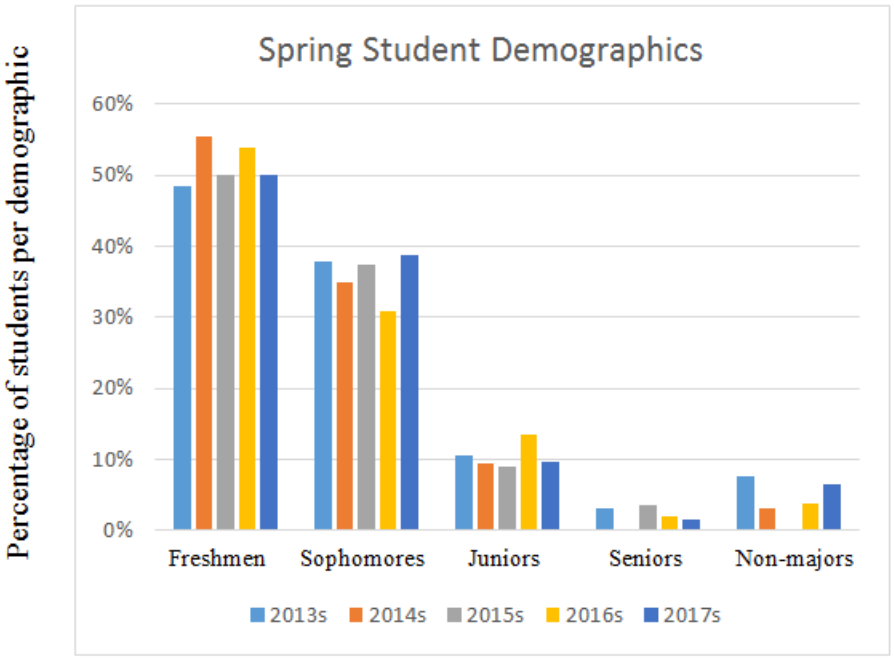

Figure 16. Student demographics for spring iterations of ECET 17700 from 2013–2017.

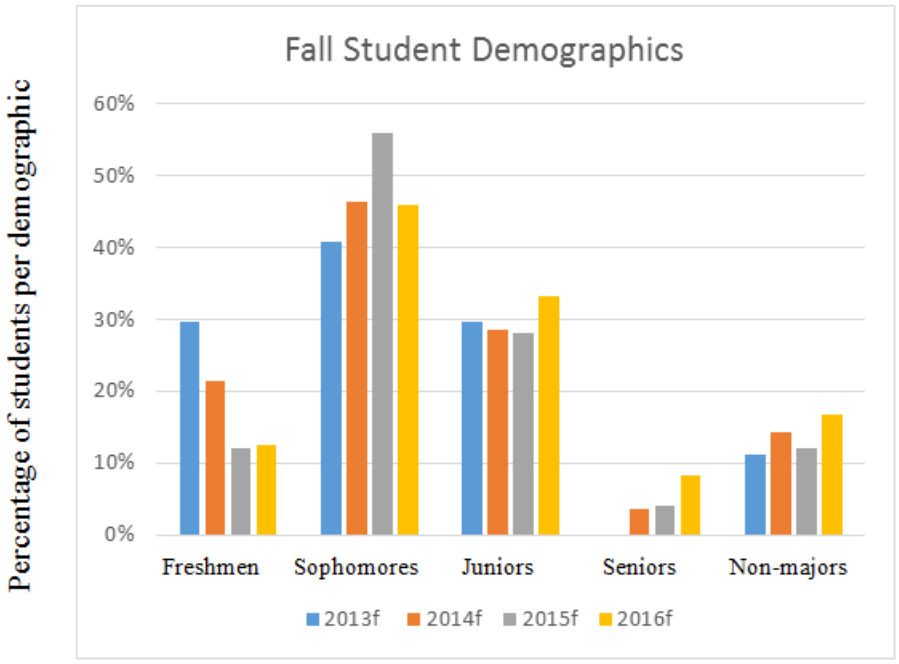

Figure 17. Demographics for spring iterations of ECET 17700 from 2013–2017.