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WIP Using Automated Assessments for Accumulating Student Practice, Providing Students with Timely Feedback, and Informing Faculty on Student Performance

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Dr. Brian Thomson is an associate professor of instruction in the department of electrical and computer engineering at Temple University in Philadelphia, PA. During his time at Temple, he taught courses in circuits, circuits lab, control systems while serving as a mentor for senior capstone projects. In 2016, he was selected as the IEEE student chapter professor of the year. He has also graduated from the provost teaching academy where he studied learning behavior, course design, and teaching methods that cultivate engaging environments to meet learning objectives. He is actively involved with departmental curriculum enhancements to provide students with a high quality education experience and prepare them for a challenging and rewarding career in this field. His research interests include control systems, signal processing, autonomous vehicles, and robotics. Prior to joining Temple, Dr. Thomson held research positions at the Navigation R&D Lab, National High Magnetic Field Lab, and Applied Research Lab. His research in feedback control for nuclear magnetic resonance applications has a patent application published and was selected as a highlight for National High Magnetic Field Lab's annual National Science Foundation report. He received his B.S. degree in electrical engineering from Rochester Institute of Technology, and his M.S. and Ph.D. degrees in electrical engineering from Penn State University. As an educator, he will continue to study and research engineering pedagogy. As a researcher, his interests include control systems, signal processing, autonomous vehicles, navigation systems, magnetic systems and magnetic resonance.

Cory Budischak, Temple University

Cory is a teacher and researcher who strives to reduce the harmful effects of energy production and use. Teaching has always been his central passion. He started as a group tutor in college, which led him to his full time career as an Associate Professor of Instruction at Temple University in the Department of Electrical and Computer Engineering. He has also taught a course "Electric Vehicles and the Grid" at the University of Delaware. He employs innovative instructional methods such as problem based learning, flipping the classroom, and teaching through interactive games. He finds it rewarding to reach students with these methods who may not have been reached by traditional lectures. His research focuses on the transition to 100% renewable energy and effective engineering instruction/support using problem based learning, flipped classroom approaches, design thinking, and co-curricular supports such as mentoring.

His main research focuses on two research questions:

1) What would our energy system look like if we make the shift towards 100% renewable energy and how much would the system cost? The research focuses not on a single energy system (electricity, transportation, agriculture), but the interaction among systems and taking a systems thinking approach.

2) How can learning and educational outcomes be improved with innovative instruction and co-curricular supports?

His research has appeared in Discovery News, The Huffington Post, Scientific American, and Rolling Stone Magazine. His outreach to the community has been featured in many local publications. He has presented his work all over the country including on the TEDx stage. He has done consulting work, including for the Chief Investment Officer of JPMorgan Chase, Michael Cembalest.

Cory received his Doctorate in Electrical Engineering from the University of Delaware. He spent 8 years at Delaware Technical and Community College in the Energy Management Department as an Instructor and Department chair before transitioning to his current role at Temple University.

When Cory is not educating or researching, he enjoys backpacking, yoga, volleyball, and hiking with his family.

Maryam Alibeik

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Abstract
Practice and feedback are critical to learning in any context. Accumulation of practice and timely feedback can support development of some of the most sophisticated skills in engineering. One of the major backbones of designing an engineering course is developing methods for students to accumulate practice and receive timely feedback on their performance. Assessments and evaluations are the tools an instructor uses to measure how much knowledge students gain from the course. Assessments are the instruments instructors develop and administer to students to measure student knowledge. Evaluation is the process of analyzing assessment results and making informed conclusions about student performance. It is important to find out a way to measure student learnings and provide feedback to them in a timely manner.

In this work-in-progress paper, we present some automated assessment and evaluation strategies that can help students accumulate practice, obtain timely feedback, and inform instructors about student performance in a timely fashion. Various techniques for automated assessments in analog circuits, digital circuits, and signals courses will be described. The process for evaluating assessments will be discussed, followed by results of implementing these assessments. Results will include indirect measurements from student surveys and faculty observations of the effects of automating assessments. Suggestions for future enhancements of these automated assessments will be provided.

I. Introduction

Practice and feedback are critical to student learning, and it is further enhanced when practice is accumulated with timely feedback [1]. Assessment and evaluation are tools to measure or observe knowledge gain from practice and feedback. With assessments instructors identify data to collect representing knowledge or skills, selects the instruments for measuring, and administers the instrument [2]. Evaluation is then the practice of analyzing assessment data and drawing conclusions from the results [2].

Multiple studies have shown how low stakes formative assessments can lower test anxiety, as well as improve student learning outcomes and self-efficacy. Malespina and Singh looked at the effect of low-stakes formative assessments on test anxiety and self-efficacy and recommend the implementation scaffolding with low stakes assessments to increase self-efficacy and lower test anxiety [3]. Malespina and Singh's results were based upon low stakes weekly or biweekly exams and did not include automated assessments with automated feedback. Marchisio et. al. looked at automatic assessment and interactive feedback in STEM courses and reported that the inclusion of automated feedback ensured that that the students would look at that feedback and take the feedback into account to understand the material better and increase their performance [4]. Barlow et. al. built upon this research by looking at the data from zyBooks which is an interactive textbook with built in formative assessments. They analyzed the actual interactions of students with the content and found that students do engage deeply with the content through this assessment delivery mechanism [5].

One of the main constraints when designing courses and especially assessments is instructor time. In an ideal situation, instructors could give assignments and tailor individual feedback to each student. As discussed previously, this kind of feedback is critical to learning. In a normal higher-ed environment, this is not practical due to instructor time constraints. We realize that not all assignments can be automated, and computer scored, but we hope to show examples of best practices to give the students rich feedback automatically and instantly. Some best practices for automated assessments that we employed at our university include:

- Multiple (or unlimited) attempts on an assessment
- Immediate feedback after each attempt that goes beyond just the score or the right or wrong answer
- Re-assigning assessments for repetition in learning
- Online/Textbook resources to support students through the assessments and to encourage self-directed learning
- Find a balance between making the assessments low stakes, but making them worth enough points to show the students they are valuable
- Evaluating student performance on automated assessments to enhance class time

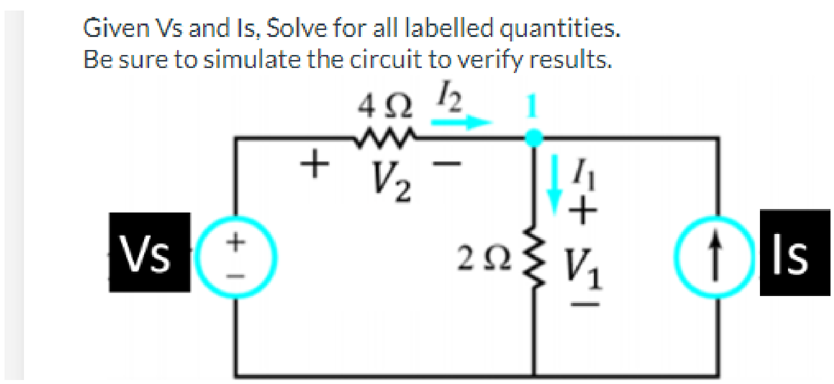
Through this use of automated assessment, students engage with the material outside of class. Instructors can view quantitative results immediately after assessment submission, informing plans for the next class session. Then class time can focus on filling in knowledge gaps and guiding students on higher level learning skills. For example, the automated assessment in a circuits class could be based upon the functionality of MultiSim and then class/lab time that week could focus on the design aspects of the circuit instead of the basic functionality of the simulation tool. In the next section, we will show different examples of automated assessment.

II. Methods

The methods described are for three courses offered every semester to sophomore / junior level students at Temple University. These courses address topics in analog circuits (ECE 2332), digital circuit design (ECE 2612) and signals and systems (ECE 3512). They are required by all ECE students at Temple and are considered traditional or foundational courses for ECE programs. We will describe the methods of automated assessments for each of these courses along with the student and instructor viewpoints.

A. Analog Circuits

The course learning objectives for analog circuits at Temple focuses on formulating mathematical models / expressions, simulating circuits, measuring results, and evaluating mathematical models by comparing analysis and simulation results. Automated assessments have been used as a tool to support these objectives using canvas LMS quizzes. These quizzes have variable input numbers such as voltage sources and resistors. Students are asked to solve for voltage, current and/or power in circuits, and the numbers change for each question. Figure 1 shows and example problem using automated assessments for this course. The quizzes are structured this way so students can focus on mathematical modeling and evaluation process rather than getting the correct numerical results for one set of input values. Fig. 1 illustrates an example of this quiz structure.



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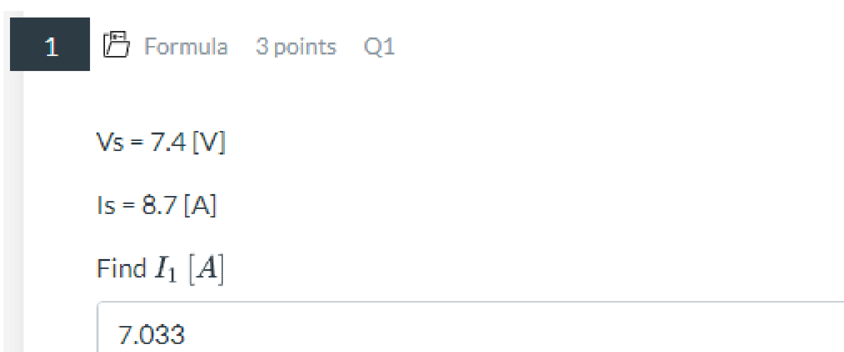

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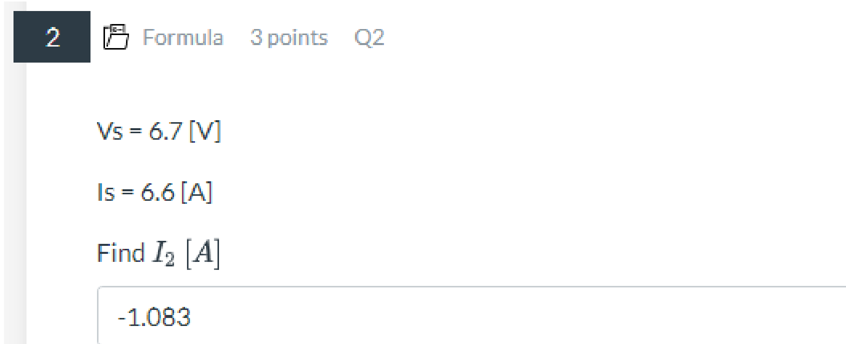
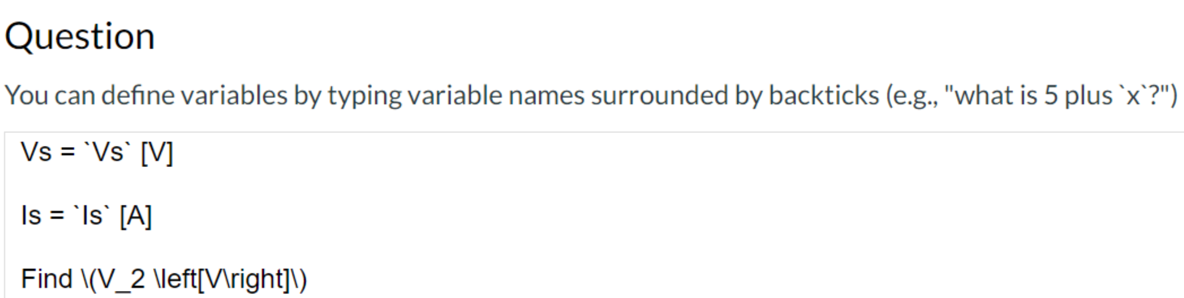


(c)

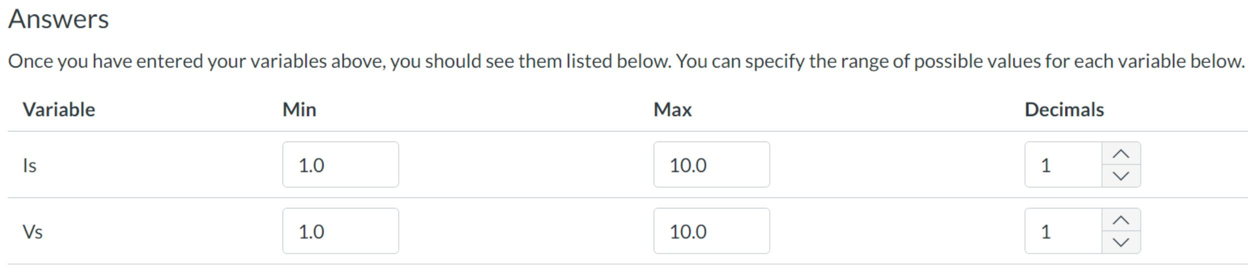
Figure 1: Analog circuit assessment, (a) circuit schematic with variable inputs, (b) question one using variable input values, (c) question two asking for different result with different inputs

In Fig. 1(a), the variable quantities are the voltage source Vs and current source Is. The students assume Vs and Is are given and generate models / expressions that produce solutions for I_1, I_2, V_1, and V_2. In Fig 1(b) and 1(c), the students are asked to enter numerical results of their solutions for two different cases. They are asked to find I_1 when Vs = 7.4, Is = 8.7 in Fig 1(a) and find I_2 when Vs = 6.7, Is = 6.6 in Fig 1(c). This emphasizes having an accurate mathematical model and expressions for their solutions. If students have these correct, then updating numbers for each question is simple.

From the instructor's perspective, setting up quizzes in this manner can be done with formula questions. The instructor defines the variable inputs, their range of values, and the formulas for generating results. Fig. 2(a) through 2(c) shows this procedure. The results can then be generated for a selected number of solutions, or combination of input numerical values. For example, in Fig. 2(d), the question produces 100 numerical results for 100 different combinations of Vs and Is ranging between 1.0 and 10.0.



(a)



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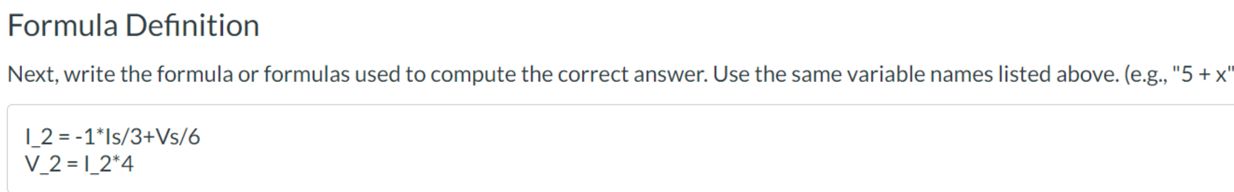

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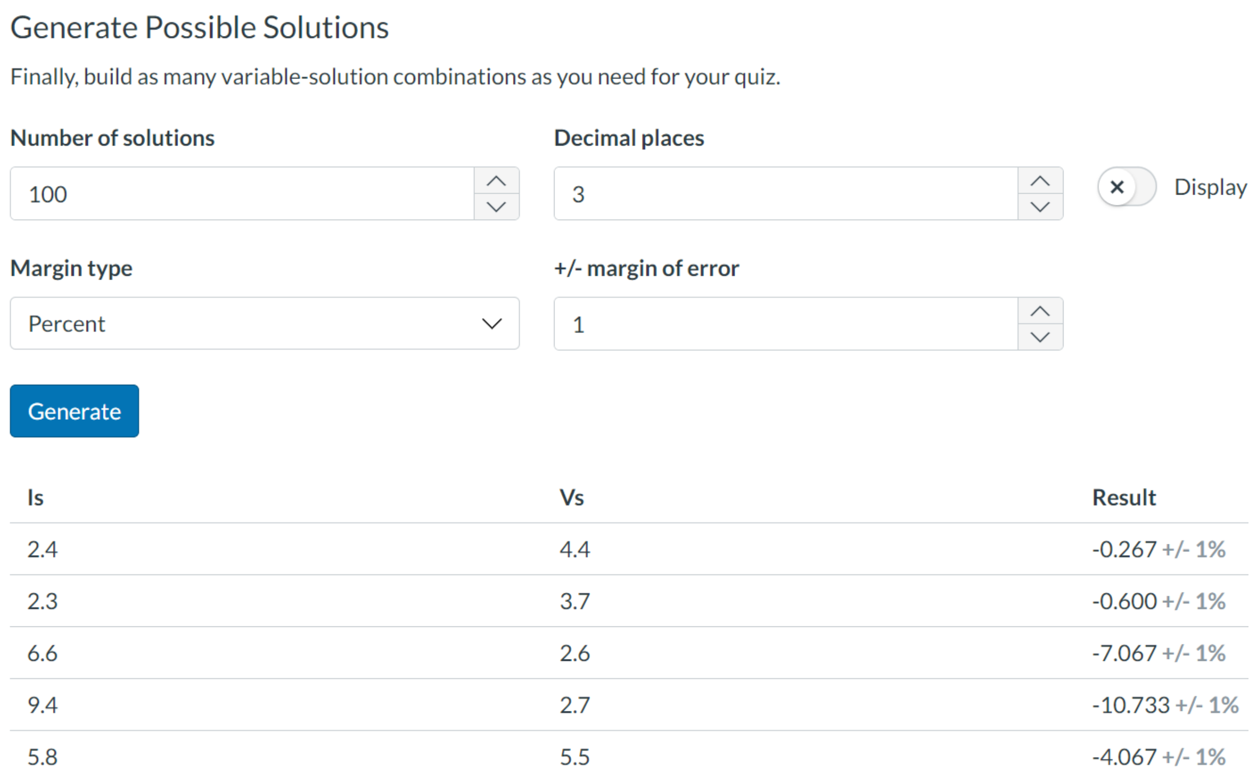


(d)

Figure 2: Instructors perspective using canvas formula questions, (a) defining variable inputs 'Vs' and 'Is', (b) setting the range for inputs from 1.0 to 10.0, (c) defining formula to produce results, (d) generating 100 numerical results for 'Vs' and 'Is' inputs from 1.0 to 10.0.

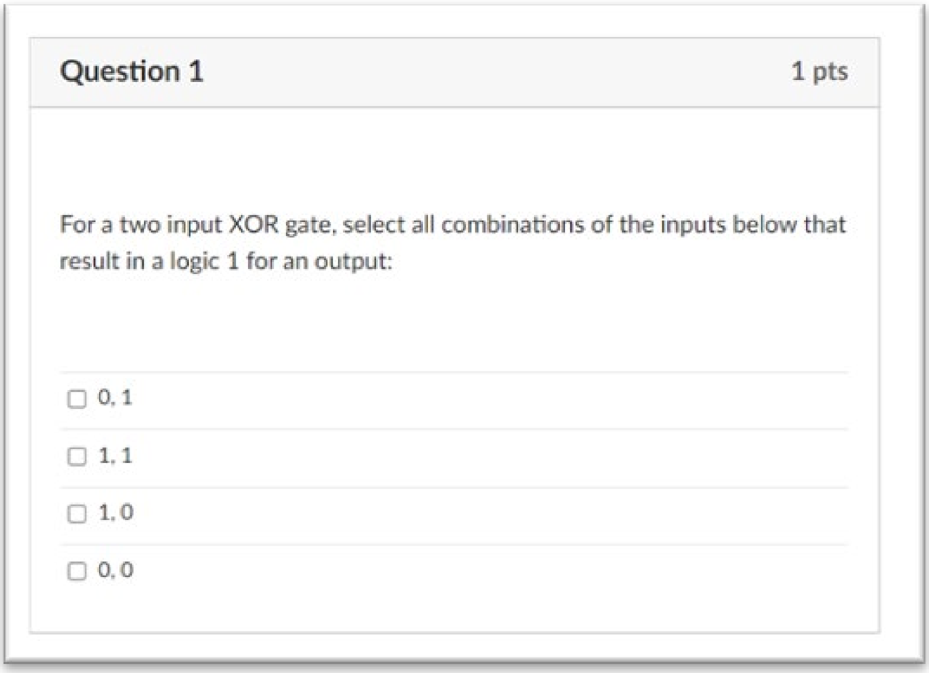
Another significant advantage of these automated assessments is the instructor can provide rapid feedback. Quiz score averages and averages per attempt can be viewed in canvas immediately after the assessment is completed. This gives the instructor the ability to review student performance, identify issues, and address them in the next class session. It gives the instructor the ability to provide rapid feedback when it is most valuable to students. These assessments have flexible structure for modifying, copying, and reassigning them. So, the instructor can reassign an assessment using limited submissions after discussing it during class time.

Using canvas formula questions for automated assessments has limitations as well when applied to analog circuits. For example, the formula questions in canvas cannot accept complex numbers. While there are ways to circumvent this, it can be tedious algebraically. Additionally, solving larger system of equations can be challenging as there are no tools for solving such systems within the formula questions. With the existing formula question features, it seems to apply best for real, algebraic expressions with smaller number of equations. It can still be a powerful tool for formative assessments.

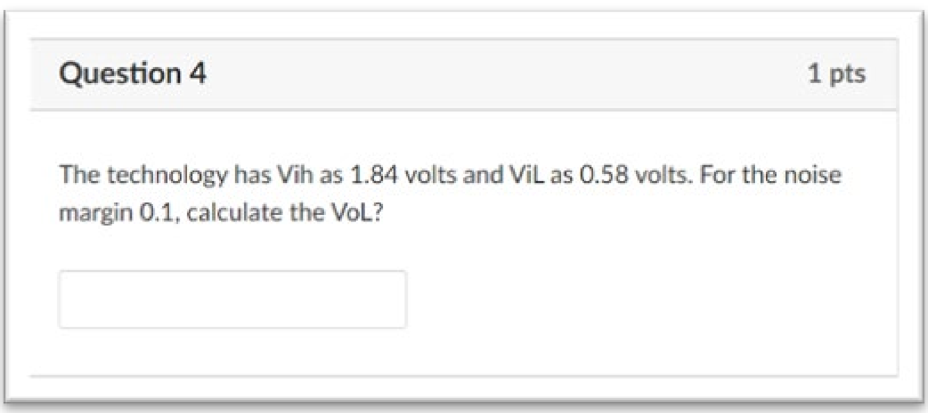
B. Digital Circuits

Automated assessment has been used in Digital Circuit Design at Temple University for several years. This is a flipped classroom; therefore, students need to go over the lecture themselves (videos) and the best way for the instructor to assess the student's progress would be through a quiz on each of the subjects. The difference between quizzes in this class and traditional quizzes is that this quiz does not have to be during class time. The students are given a period in which they can complete their quizzes.

This class consists of 10 modules. Each module has a separate quiz. To give students timely feedback on their performance, these quizzes are assessed automatically. Each student can take each quiz 3 times and at the end of each attempt, they will see their grades and incorrect questions. It is worth mentioning that the correct answer will not be revealed to the student until the end of the third attempt. This method helps students to get on-time feedback so that they have an idea of what level they are standing in class. Questions in the quizzes for this class are mostly filling the blank or multiple-choice questions. This will make the automated assessment more precise and accurate. Fig. 3(a) shows an example of a multiple-choice question while Fig. 3(b) shows an example of a fill-in-the-blank question.



(a)



(b)

Figure 3. (a) example of a multiple-choice question, (b) example of a fill in the blank question.

For the questions with numerical answers, there is normally a tolerance embedded in the answer in case a student does not have the exact number. If the answer has a decimal point, then in the problem statement it will be mentioned how many decimal points are needed. There also exist questions with multiple answers as shown in Fig. 4.

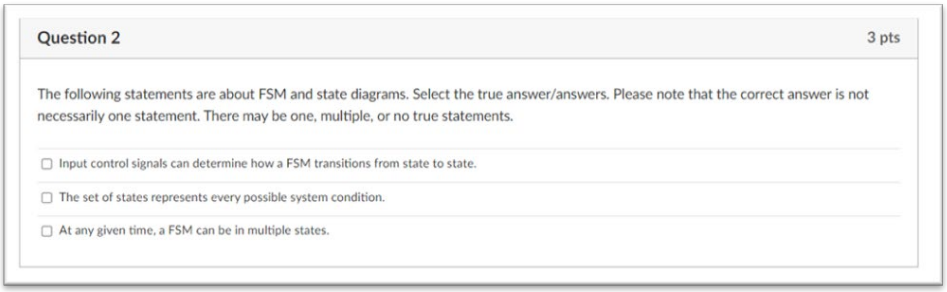


Figure 4. example of a question with multiple correct answers

From an instructor's point of view, this method will first save a lot of time that can be spent on the course material and improving the course, as well as giving the instructor an option to assess each student's pace and the overall level of the class. Using this information, the instructor will be able to adjust the class pace.

Another great advantage of automated assessments is to give the instructor a quick statistic on the quiz overall and individual questions. Fig. 5 shows an example of quiz statistics that the instructor can see as soon as the students start taking the quiz.

As you can see in this figure, the average time spent by the whole class as well as the individual quiz time spent by each student is available through the statistics.

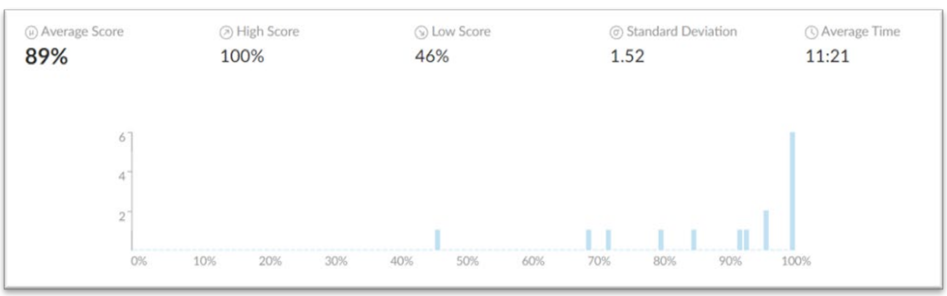


Figure 5. quiz statistics using the automated assessment

"Student analysis" and "item analysis" are also available through the statistics. These options will help the instructor to get more details on students' responses on each attempt and the difficulty of the quiz is also assessed based on the student's performance. Below the quiz statistics, the instructor can find the statistics for each question as shown in Fig. 6.

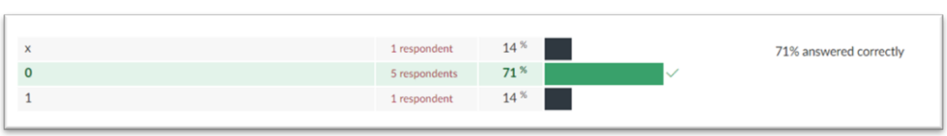


Figure 6. statistics for each individual question

Since quizzes are individual, there should be a way to proctor students while they are doing these quizzes. We are using Proctorio as an online proctor, which will record their audio, video, and screen while they are taking the quiz.

C. Signals and Systems

A course on signals and systems also utilizes a few different types of automated assessments. In this course, the students learn the fundamental math of signals and systems and how to apply these concepts through MATLAB projects. Here, we present two different types of automated assessments as well the feedback that is provided to faculty to help them fill the gaps in student knowledge during class time.

You can see in Fig. 7 an example of an automated assessment for graphical convolution. This is from the interactive book (know as zyBooks) titled "NI Engineering Signals and Systems (2e) – Interactive Edition" [3]. Before getting to this part in the book, the student has read a very brief overview of graphical convolution. Then they interact with a nine part animation that shows how to calculate an RC circuit response to a rectangular pulse. Once they have completed this animation, the student then tries a similar problem on their own (see the bottom of Figure 7). The student can attempt this problem as many times as they would like and the solution is available to them if they cannot get it right.

Figure 8 shows the analytics which the instructor of the course can access. You can see that the students spent 5:05 on the question at the bottom of Fig. 7 and on average it took 2.72 attempts. This means that even though students were given the option of just showing the answer and entering it in, they decided to take the time and answer the question more than 2 times themselves.

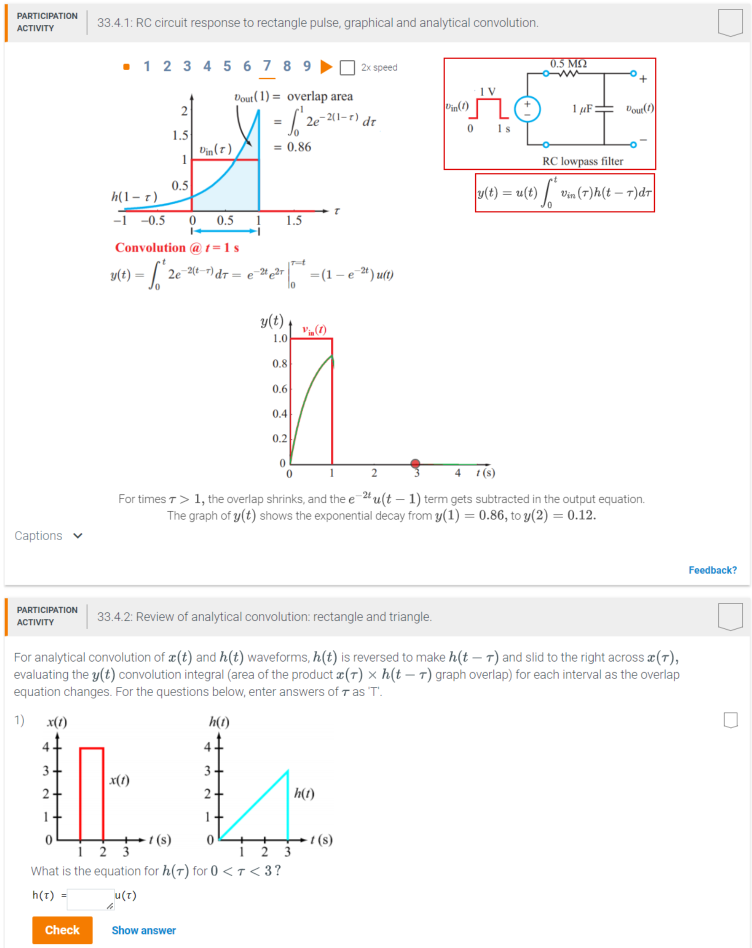


Figure 7: A participation activity to teach graphical convolution. The student first sees an animation with 9 steps (top) that explains the problem solving process and then gets a similar problem where they check their answer before seeing the solution

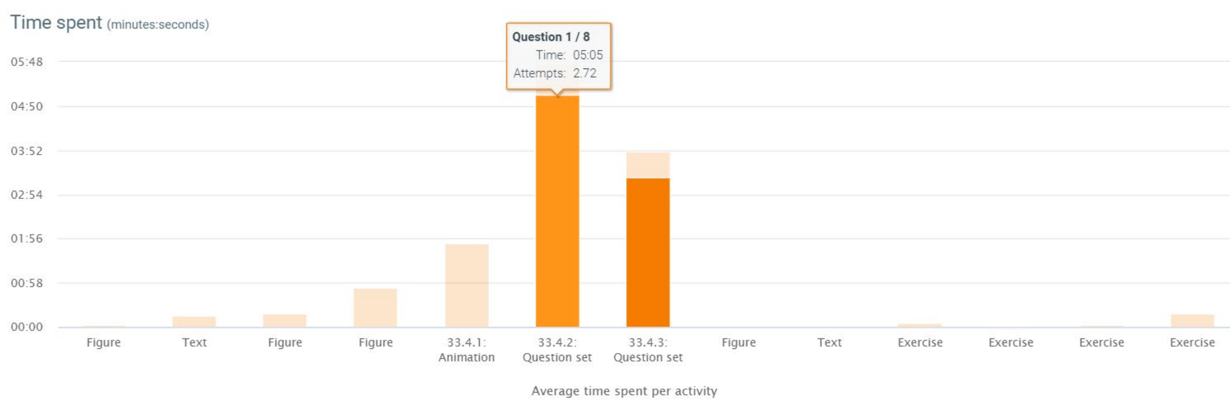


Figure 8: Instructor view of analytics with the tool tip over Question 1 in section 33.4.2 seen in Figure . This shows the time spent as well as the number of attempts.

The second example used in this class is MATLAB grader. The students in this class use MATLAB for certain projects in the course. In one such project, students must design a filter to get rid of 60Hz noise in an EKG signal. Before MATLAB grader was instituted, students had a difficult time with the exact use of the built in MATLAB functions tf, bode, and lsim. For this automated assignment, the students are given starter code which they need to modify in order to display the response and output vs. time of an RLC circuit. Students are asked to fill in the tf, and lsim functions for the capacitor and the resistor. These functions are already filled in for them for the inductor as an example. You can see the steps that are assessed in Fig. 9. The students' code is automatically evaluated in real time, and they are given feedback if they fail a certain test. Fig.10 gives the instructor feedback as to which test was the most difficult. It can be seen that 47% of students passed the test with just one submission while others took many more and 3 students submitted the problem but did not solve it.

Figure 9: Tests that students code must pass when analyzing an RLC circuit. H is a transfer function, yt is an output function y(t) , C is capacitor, and R is resistor.

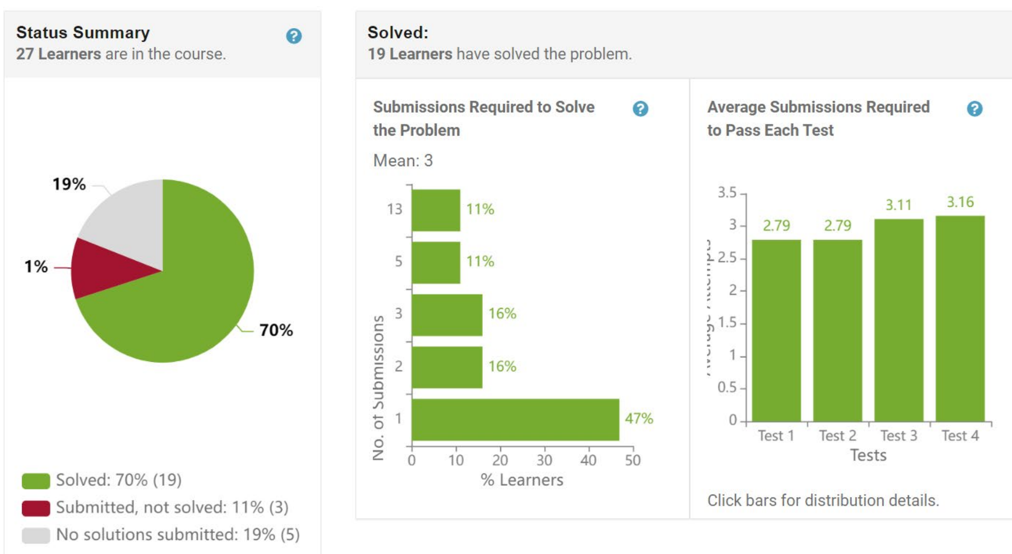


Figure 10: Feedback to the instructor for students solving the full problem and the tests detailed in Fig. 9. Note the no solutions submitted were students who had dropped the class during the drop/add period.

III. Results

At the end of each term, students complete course evaluation forms. Here is some of the feedback we have received from these forms about the assessments in the courses described above:

Evaluation Form Question : What aspects of the course contributed most to your learning?

- "The constant small and regular assignments kept the material in my head and helped me learn more."
- "solving problems in class. Zybook examples where very interesting and helpful"
- "... zybooks were also useful in understanding coding etiquette"
- "...the zybooks were helpful and provided good practice material."
- "I really liked the aspect of watching videos before class and then doing practice problems or having a discussion about it in class. This type of approach should be used in more classes beacuse it really is effective"
- "The homework assignments that were assigned almost everyday and the videos we needed to watch before class really helped my learning."
- "… Most of the canvas assignments contributed to my learning…."
- "The amount of practice problems and assignments contributed most to my learning."
- "The post-class quizzes were a great way to check our understanding of the material."
- … I found that the quiz problems were always challenging but fair, and a good assessment of whether I truly understood the material…"

As instructors, we find that the more time we put into high quality automated assessments, the richer our in-class time becomes. As an example, after students completed the automated assessment detailed in Fig. 9 and Figure 10, the students had time to work on designing their filter to eliminate 60Hz noise from an EKG signal. As they were working, there were many discussions with classmates as well as the instructor on what the tradeoffs were and what the physician reading the EKG would find important. They were connecting the fundamental signals skills they learned to the context in the real world and the engineering design process which is much more important than being able to correctly calculate the fourier transform of a signal. Therefore, this kind of automated formative assessment allows more time in class for deep problem solving and design which is something that ABET requires in its student outcomes.

By automating assessments, instructors can quantitatively track student performance immediately after assignment submission. This enables the instructor to adapt class time activities based on student results and provide rapid, targeted feedback towards areas that students find most challenging. Instructors can re-assign these assessments or modify them to help students accumulate practice.

IV. Summary and Conclusions

Both the instructors and the students have found the addition of these automated assessments helpful for these courses. However, there is still plenty of development that can be done. With more time and effort, we hope to add more quantitative tracking to student progress and use this to continue routine adaptations of class activity plans based on the immediate performance results of students. Since this is a work in progress paper, we also hope to garner feedback from the engineering education community of ways that we can measure the impact of these assessments.

Here are several options we are considering for future work which are grounded in past studies:

1. Measuring student's self-efficacy and test anxiety similarly to Malespina and Singh [4]
2. Gathering information on student interaction such as first time wrong and time spent on the formative assessment activities as discussed in Barlow et.al. [5]
3. Marchisio et.al. Look at Nicol and Macfarlane-Dick's Model of Feedback and Hattie and Timperley's Model of Feedback to analyze similar automated assessments in Mathematics and Physics courses. We could repeat their methodology for our courses in Electrical Engineering. [6]

V. References

[1] M. W. B. M. D. M. C. L. a. M. K. N. S. A. Ambrose, How Learning Works: Seven Research-Based Principles for Smart Teaching., San Francisco, CA: Joseey-Bass, 2010.

[2] R. M. Felder and R. Brent, "Teaching and Learning STEM: A Practical Guide," San Francisco, Jossey-Bass, 2016, pp. 84 - 86.

[3] Y. Adibi, M. Atkins, N. Sambamurthy and M. Sarraf, NI Engineering Signals & Systems (2e) - Interactive Addition, zyBooks, 2021.

[4] A. Malespina and C. Singh, "Gender differences in test anxiety and self-efficacy: why instructors should emphasize low-stakes formative assessments in physics courses," *European Journal of Physics,* vol. 43, no. 3, 2022.

[5] R. Barlow, O. Rios, J. Eakins and A. Rodriguez, "Evaluating the benefits of adding interactive elements to traditional print mechanical engineering textbooks," in *2022 ASEE Annual Conference & Exposition*, Minneapolis, 2022.

[6] M. Marchisio, A. Barana, M. Fioravera, S. Rabellino and A. Conte, "A Model of Formative Automatic Assessment and Interactive Feedback for STEM," in *2018 IEEE 42nd Annual Computer Software and Applications Conference (COMPSAC)*, Tokyo, 2018.