2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #36969

Create Multi-Part Problems with Random Parameterization on Blackboard and Canvas Similar to ”Mastering” and ”Connect”

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Abstract

In active learning, similar problems with random parameterization assigned to different students effectively encourage independent work while inhibiting plagiarism. Pearson's Mastering platform and McGraw Hill's Connect platform are the leading competitors on the market to provide online customized problem definitions with randomized parameterization. The author used Mastering in a class in Fall 2019 and Connect in another class in Spring 2020, as a trial for free (and the author was grateful for the publishers' support). The students commented that these platforms were helpful, but their price tags were prohibitive. Therefore, the author used Blackboard to create similar problems in Fall 2020 and Spring 2021, skipped Fall 2021 given her sabbatical leave, and switched to Canvas (due to campus-wide adoption of Canvas to replace Blackboard) to do the same in Spring 2022 and Fall 2022. It takes time to set up such enhanced multi-part problems on Blackboard or Canvas, but these problem sets are reusable, and the student responses are positive. This paper describes how to create such multi-part problems with random parameterization on Blackboard and Canvas, and presents the evolvement of student perceptions from Fall 2019 to Fall 2022, to reflect on the impact of the pandemic.

Introduction

Active learning is proven to be an effective pedagogy to improve student performance [1], where the students may be engaged in problem-solving, experiential learning, teamwork, a flipped classroom, or other learning modalities. Timely feedback is crucial for the students to make steady progress in active learning: The instructor's feedback is important, while online feedback allows students to verify their answers by themselves in real time. Online quizzes have existed for decades, which are convenient to grade if an answer is right or wrong, but the questions are graded independently, while a complex problem often involves multiple steps, requiring a problem definition with multiple related parts/questions, instead of just one independent question. To help promote student interest in attempting a similar but non-identical problem and prevent plagiarism, the author wants to randomize the parameters in a problem, and its multiple parts/questions need to refer to the same set of parameters.

Pearson's Mastering platform [2][3] and McGraw Hill's Connect platform [4] have built-in the question design with multiple parts. The intermediate variables could be defined by formulae and stored to derive the correct final answers to compare with the student answers. A tolerance by percentage or a numeric range could be added to the correct answers to handle computational discrepancies. These are all the desired features of a multi-part problem with randomized parameters. Please note that for e-books published by Pearson or McGraw Hill, there are often associated problem banks that an instructor can use directly from the specified e-books on the Mastering or Connect platforms. However, those e-books might not be consistent in the terminology of the textbooks other instructors use such as current direction (electron flow or conventional flow), zero-phase definition (sine or cosine), etc., or the instructors might simply want to define the problems themselves with full control instead of being limited by a problem

bank. That's the other motivation for the author to customize the problems, even on Mastering and Connect, and subsequently on Blackboard and Canvas.

To obtain the effect of a multi-part problem with randomized parameters in a common Learning Management System (LMS), such as Blackboard and Canvas, the author used "Question Set" on Blackboard and "Question Group" on Canvas to randomize the problem selection from a set of similar problems with different parameters, and these problems were fill-in-multiple-blanks type of question to become essentially a multi-part problem. Note that these similar questions in Question Set or Question Group need to be pre-designed numerically but not generated by the LMS. The key to using the LMS for the enhanced quiz's purpose is to create a set of similar problems with different parameters in a batch and set up the answer comparison with proper tolerance. Blackboard's online quizzes allowed tab-separated CSV file upload for many of its popular quiz formats. In Fall 2020, the author used Excel spreadsheets to tabulate the input values in multiple sets and automatically generated the intermediate and output values, and then followed the Blackboard CSV file template to upload multiple problems with different parameters in one go. The author recently discovered that another instructor used a similar approach in Spring 2021 to generate such questions on Blackboard in Excel [5]. When the author's campus adopted Canvas, the course content exported from Blackboard could be imported into Canvas, and hence these problems needed not to be redefined, although the grading criteria needed to be adjusted. Admittedly, it is not as easy in LMS as using Mastering or Connect to create multi-part problems with random parameterization, given the limited features of LMS, but it is doable.

The author started this effort to use randomized parameterization in multi-part problems before the pandemic, aiming to support active learning. Incidentally, this approach proved to be very beneficial during the pandemic when the in-person interaction was cut back. Now that the pandemic is nearly abated, the students still find this approach beneficial and want to continue.

However, with Artificial Intelligence (AI) gaining strides in its development to generate plausible content, any online approach needs to take into account the potential of cheating and explore how the assessment could be carried out with authenticity.

This paper will first present the desirable features of Mastering and Connect, and then explain how to set up these equivalent features in Blackboard and Canvas. The student survey from Fall 2019 to Fall 2022 will be presented to demonstrate learning effectiveness and student perceptions. The last section will conclude this paper with future work.

Features of Mastering

In Fall 2019, the author experimented with Pearson's "Mastering" online platform in an AC circuits course and the students appreciated the multi-part problems with sequential steps guiding their problem-solving, and they loved the real-time feedback to their work. Mastering also allows several formats including LaTeX interpreter in problem definition and answers.

There are some problem banks associated with the e-books published by Pearson, from which one could copy and revise a problem to fit it into a customized problem. Or else, one could set up the multi-part problem from scratch.

The input variables could be set to be randomized within a numerical range, or from a limited set of values. As shown in Figure 1, the "Step" variable in the "Value" setting in Pearson's Mastering platform controls the step size in data generation. For example, the first variable E1_rms ranges from 11 to 20 with a step size of 1 and hence there are 10 possible values (11, 12, …, 20). The other input variables are also randomized similarly, and hence there are many combinations of potential input variable values. By controlling the value range and step size, one can specify how many versions of randomization should occur.

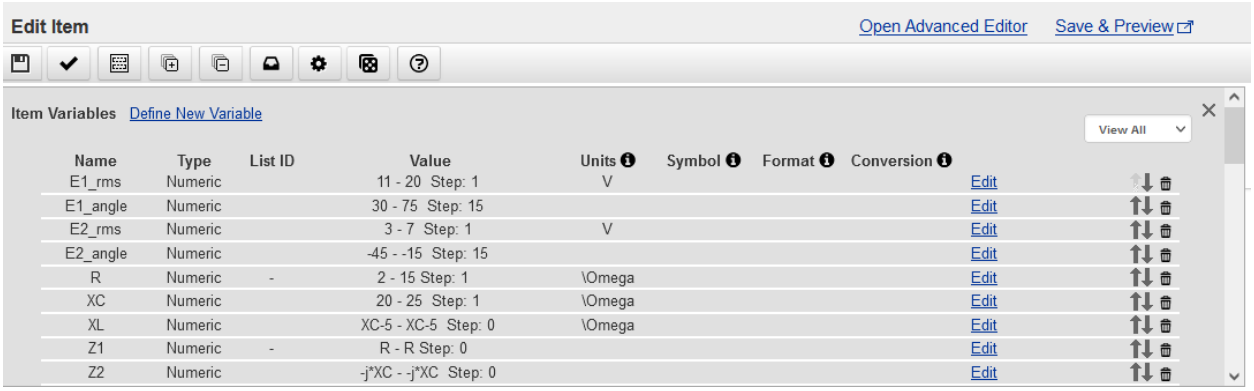


Figure 1. The input variables defined in Pearson's Mastering with a non-0 Step size

After the input variables are defined, the intermediate variables and ultimately the output variables can be defined using the often-used mathematical functions including trigonometric functions, polynomial functions, etc. using the input variables, as shown in Figure 2. With each set of substantiation of the input variables, the values of the subsequent variables will be updated accordingly. Each student will see a substantiation of one set of variable values.

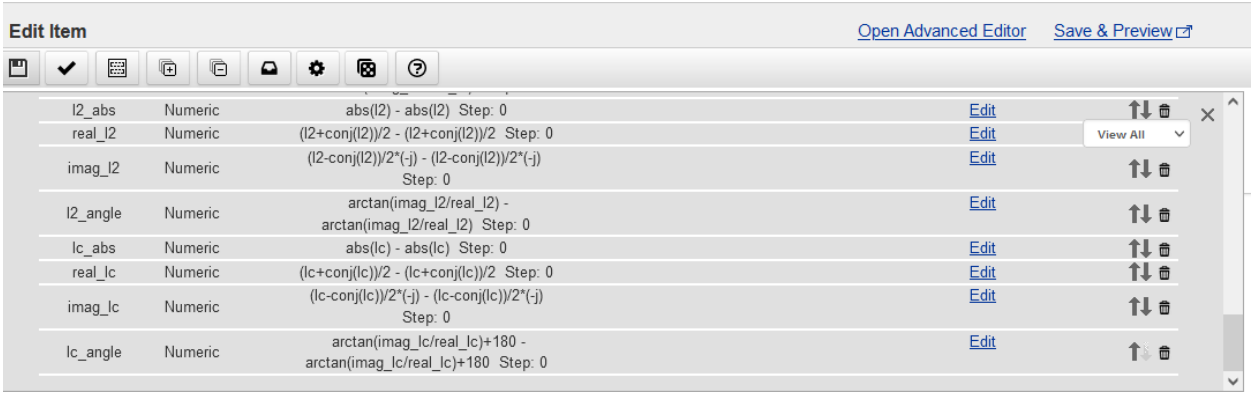


Figure 2. The intermediate and output variables defined in Pearson's Mastering with 0 Step size

The accuracy matching criteria in grading the student answers could be set in several ways. The tolerance to the numerical answers could be defined by percentage or a numerical range. Units could be considered as part of the answers. The text-based answers could use pattern matching with keywords.

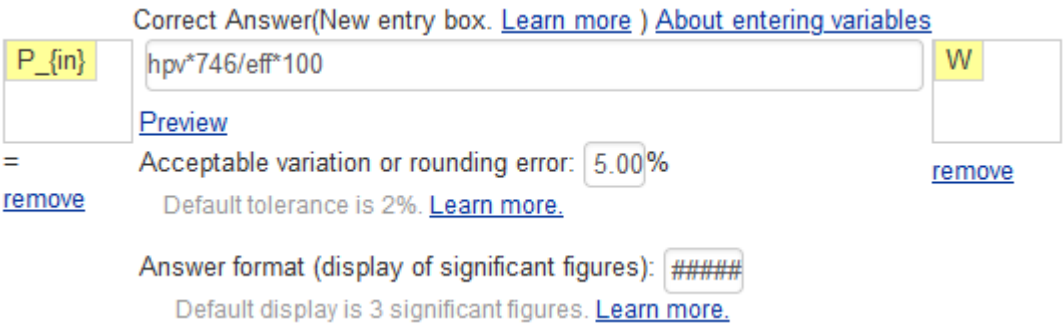


Figure 3. Setting answer-matching criteria in Pearson's Mastering

Overall, Mastering is a capable and versatile platform with neat features to define multi-part problems with randomization. The students commented that it was easy to use, and the interpretation of the responses was straightforward. If not for the price tag (understandably), it would be adopted much more widely.

Features of Connect

In Spring 2020, the author experimented with McGraw Hill's "Connect" online platform in a control theory course, and the students provided similar feedback on Connect as on Mastering. Spring 2020 was when many campuses switched all their courses online suddenly due to the pandemic and McGraw Hill made Connect free to help campuses make this transition, which was highly appreciated.

Connect organizes the multiple parts of a question in sections. Parameter variation is allowed in the Worksheet type of questions.

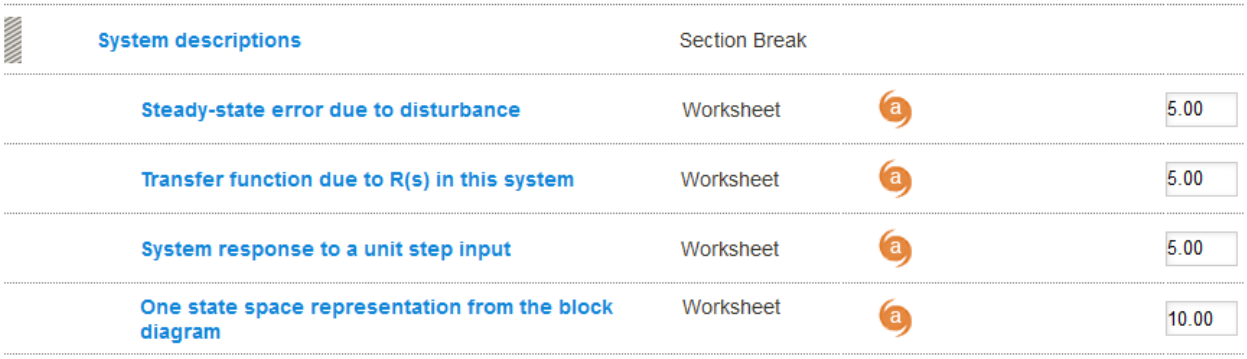


Figure 4. Problem organization in McGraw Hill's Connect

Besides many similar features of Mastering with parameter randomization and multiple parts of a problem, Connect's problem bank often provides very detailed explanations, as shown in Figure 5, as well as relevant tutorials and references, which are handy for students to learn at their own pace. The learning support feature at McGraw Hill has been nearly perfected in the ALEKS system, which has been adopted by many campuses for incoming undergraduate students' math placement, which provides a built-in assessment of student math skills and generates customized exercise problems for the students to strengthen their relatively weak areas before the students take the next attempt at it. Although Connect has not been as thorough in student learning support as ALEKS, it is user-friendly and supplies helpful information where it is needed.

State-space model of a fourth order system.

Obtain the expressions for the matrices A, B, C, and D for the state-variable model given. The outputs are x_2 and x_2.

$\dot{x}_1 = x_3$

$\dot{x}_2 = x_4$

$\dot{x}_3 = \frac{1}{10}\left(-40x_1 + 25x_2 - 8x_3 + 5x_4\right)$

$\dot{x}_4 = \frac{1}{5}\left(\left(f(t) + 25x_1 - 25x_2 + 5x_3 - 5x_4\right)\right.$

Where

$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -4 & 2.5 & -0.8 & a \\ 5 & b & 1 & c \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ d \end{bmatrix} \quad C = \begin{bmatrix} e & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ f \end{bmatrix}$$

For the matrix A, the value of a is [0.5], b is [-5], and c is [-1].

For the matrix B, the value of d is [0.2].

For the matrix C, the value of e is [1].

For the matrix D, the value of f is [0].

Explanation:

For the inputs of the state equations, the following relation holds good

A*x* = b

The matrix A corresponds to an ordered fashion of coefficients of x_1, x_2, x_3, and x_4. The vector *x* contains the variables x_1, x_2, x_3, x_4, and the vector b
contains the right-hand side of the equations that are constant values.

Hence, comparing the coefficients of the input equations, we get

$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -4 & 2.5 & -0.8 & 0.5 \\ 5 & -5 & 1 & -1 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0.2 \end{bmatrix}$$

For the output of the state equations, the following relation holds good

y = C*x* + D*u*

where the vector *y* contains the output variables

Hence, comparing the coefficients of the output equations, we get

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \quad D = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Hints

Hint #1

References

Worksheet	State-space model of a fourth order system.	Difficulty: Medium

Report a content issue

Source: Instructor created or modified

Tips and Tutorials

Figure 5. Problem explanation in McGraw Hill's Connect

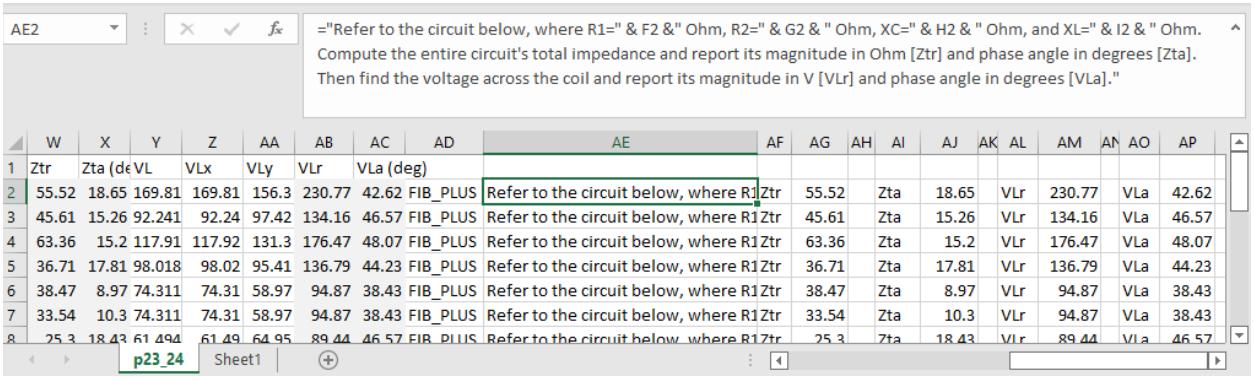
From the instructor's point of view, there are a few drawbacks to Connect by design. Connect does not allow problem editing after the students have attempted the quiz, as their philosophy is that all students should see the equivalent/same test, however, it is inconvenient as the instructor cannot go back to fix a typo and a typo is prone to happen especially when the problems are defined by the instructor. The author contacted Connect about disabling this restriction but was not able to change it. Another limitation is personal preference. Connect uses Math Editor rather than LaTeX, which can be restrictive and tedious at times.

Multi-Part Problem with Randomized Parameter Setup on Blackboard

Both Mastering and Connect platforms have demonstrated versatile capabilities to support customized definitions of multi-part problems with random parameterization. However, the cost of Mastering or Connect is a hurdle to students. Therefore, the author used the existing LMS, including Blackboard (Fall 2020 and Spring 2021) and Canvas (Spring 2022 and Fall 2022), and set up a "Fill in Multiple costs" type of quiz problem in a "Question Set", to give students essentially the similar experience as on Mastering or Connect.

Note that, on Blackboard, the "Calculated Formula" type of quiz could handle some parameterization, but it does not allow multi-parts in a problem, and there is no way to define the intermediate variables except the final answer.

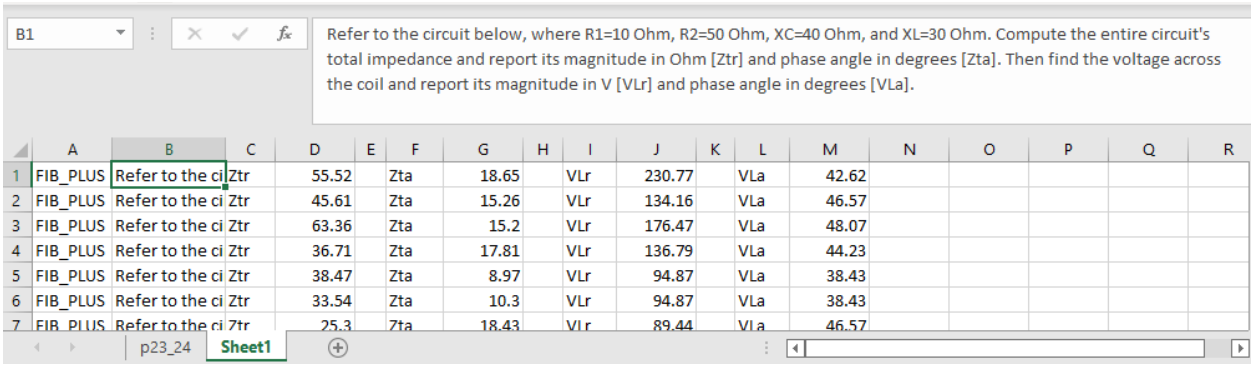
Blackboard allows CSV file upload to create a test. Therefore, the groups of similar problems can be defined in Excel to specify the sets of input parameters, and then use Excel functions to calculate the intermediate variables and the final answers. As shown in Figure 6, all the variables are defined from column A to column AC, while the grayed cells are used in the problem description and answer checking. Column AD is the keyword to declare the type of questions on Blackboard. Column AE is the problem description, which is a long string calling the values of the variables. Columns AF and onwards are the answers listed in a format that Blackboard expects. The instructor can change the input variables' values in the earlier columns, and then the values of all the subsequent columns are updated. Each row is corresponding to one instantiation of this problem with one set of parameters.



	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1	Ztr	Zta (de	VL	VLx	VLy	VLr	VLa (deg)													
2	55.52	18.65	169.81	169.81	156.3	230.77	42.62	FIB_PLUS	Refer to the circuit below, where R1	Ztr	55.52		Zta	18.65		VLr	230.77		VLa	42.62
3	45.61	15.26	92.241	92.24	97.42	134.16	46.57	FIB_PLUS	Refer to the circuit below, where R1	Ztr	45.61		Zta	15.26		VLr	134.16		VLa	46.57
4	63.36	15.2	117.91	117.92	131.3	176.47	48.07	FIB_PLUS	Refer to the circuit below, where R1	Ztr	63.36		Zta	15.2		VLr	176.47		VLa	48.07
5	36.71	17.81	98.018	98.02	95.41	136.79	44.23	FIB_PLUS	Refer to the circuit below, where R1	Ztr	36.71		Zta	17.81		VLr	136.79		VLa	44.23
6	38.47	8.97	74.311	74.31	58.97	94.87	38.43	FIB_PLUS	Refer to the circuit below, where R1	Ztr	38.47		Zta	8.97		VLr	94.87		VLa	38.43
7	33.54	10.3	74.311	74.31	58.97	94.87	38.43	FIB_PLUS	Refer to the circuit below, where R1	Ztr	33.54		Zta	10.3		VLr	94.87		VLa	38.43
8	25.3	18.43	61.494	61.49	64.95	89.44	46.57	FIB_PLUS	Refer to the circuit below, where R1	Ztr	25.3		Zta	18.43		VLr	89.44		VLa	46.57

Figure 6. Parameter generation in Excel for Blackboard CSV upload

Once the values for each instantiation of a problem are set, one can copy the values of columns AD and onwards that Blackboard expects in the CSV file upload onto a new sheet, as shown in Figure 7. This Excel sheet is then saved as a tab-separated file to upload onto Blackboard.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	FIB_PLUS	Refer to the ci	Ztr	55.52		Zta	18.65		VLr	230.77		VLa	42.62					
2	FIB_PLUS	Refer to the ci	Ztr	45.61		Zta	15.26		VLr	134.16		VLa	46.57					
3	FIB_PLUS	Refer to the ci	Ztr	63.36		Zta	15.2		VLr	176.47		VLa	48.07					
4	FIB_PLUS	Refer to the ci	Ztr	36.71		Zta	17.81		VLr	136.79		VLa	44.23					
5	FIB_PLUS	Refer to the ci	Ztr	38.47		Zta	8.97		VLr	94.87		VLa	38.43					
6	FIB_PLUS	Refer to the ci	Ztr	33.54		Zta	10.3		VLr	94.87		VLa	38.43					
7	FIB_PLUS	Refer to the ci	Ztr	25.3		Zta	18.43		VLr	89.44		VLa	46.57					

Figure 7. CSV file set-up for Blackboard CSV upload

Note that in Figure 6, the problem description string recalls many cells' values by the cell location, but in Figure 7, the problem description becomes a string with fixed values. The parameter randomization does not happen at LMS but is generated by the instructor in Excel.

On Blackboard, "Question Set" is used to include all these similar problems from CSV file upload, and the instructor can choose to select one out of these many problems for each student to see. The problem settings could be further adjusted to allow partial credit, add an image for a diagram, randomize the answer choices, and/or choose proper answer-matching criteria. These extra settings cannot be set up during CSV file uploading.

A limitation of Blackboard is that the answers are matched as text, rather than numbers, and hence truncation rather than error percentage is used in answer validation. For example, the instructor may require the students to type 3 decimal digits, but only the first 2 decimal digits are compared with the correct answer, while the 3rd decimal digit is ignored, as a tolerance.

Multi-Part Problem with Randomized Parameter Setup on Canvas

Canvas does not allow CSV file upload but can import the exports from Blackboard and hence the author is able to continue to use the set of problems without redefining them, otherwise, the author would explore the Python-based API (canvasapi) to automate the problem definition procedure on Canvas.

The "Question Set" on Blackboard becomes "Question Group" on Canvas, as shown in Figure 8. The instructor can set it to choose one or more problems out of this Question Group and assign a point value. Each problem within the Question Group can be individually edited if needed.

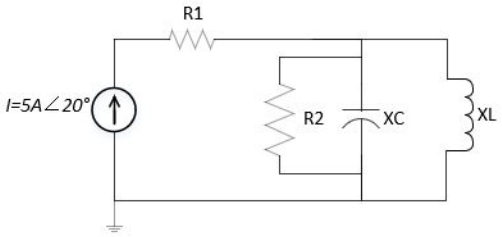
The "Fill-in-multiple-blanks" type of problem is continued to be in use, to address the multiple parts of analyzing a circuit with a set of parameters. The common input current source is indicated in the diagram, while the component values are provided in the problem description, which varies among the problems in this Question Group.

Canvas does not allow answer pattern matching like in Blackboard and hence a range of values around the correct answer would need to be added as correct to accommodate approximation errors in a multi-step problem. As shown in Figure 9, the correct answer from Excel calculation is listed as the first correct answer, while a few other correct answers with a few digits off are also listed to be correct, to allow tolerance.

Question Group Pick 1 questions, 10 pts per question

Question

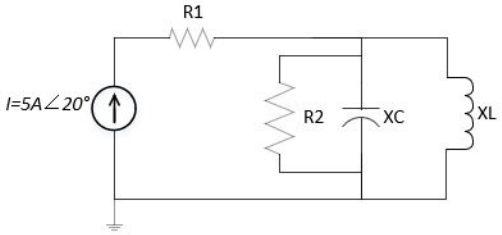
Refer to the circuit below, where R1=8 Ohm, R2=20 Ohm, XC=40 Ohm, and XL=20 Ohm.



Compute the entire circuit's total impedance and report its magnitude in Ohm [Ztr] and phase angle in degrees [Zta]. Then find the voltage across the coil and report its magnitude in V [VLr] and phase angle in degrees [VLa].

Question

Refer to the circuit below, where R1=10 Ohm, R2=30 Ohm, XC=40 Ohm, and XL=25 Ohm.



Compute the entire circuit's total impedance and report its magnitude in Ohm [Ztr] and phase angle in degrees [Zta]. Then find the voltage across the coil and report its magnitude in V [VLr] and phase angle in degrees [VLa].

Figure 8. Question Group setting on Canvas

2. natural frequency ω_n and damping ratio ξ.

Write down ω_n here (with 2 decimal digits after proper rounding): [wn].

Write down ξ here (with 2 decimal digits after proper rounding): [k].

3. Is it (A) underdamped, (B) critically damped, or (C) overdamped?

Write down your choice of A, B, or C here (without parenthesis): [c].

Show Answers for wn

Correct Answer 2.82

Correct Answer 2.83

Correct Answer 2.84

Figure 9. An example of answer matching on Canvas

For other LMS such as Moodle or Brightspace, they provide similar quiz types, and the idea presented in this paper could be implemented similarly on other LMSs.

Usage of Multi-Part Problems with Parameter Randomization in Course Design

Given the author's teaching assignment, the following courses have incorporated such multi-part problems with parameter randomization from Fall 2019 to Fall 2022.

- Circuit Analysis II
- Network Theory II
- Instrumentation and Networks Laboratory
- System Dynamics and Control

The following learning support or assessment instruments have incorporated them to various degrees.

- Homework
- In-class exercise
- In-class quiz
- Midterm
- Final

For assignments, the author might set up the first few steps of a problem with unlimited online verification while the later steps do not have any support so that the students will know that they are on the right track to solve the problem, and they still need to think independently.

For quizzes, the problems are often short and direct. It is a quick way to assess the class's progress and help the students identify areas to improve.

For exams, the students will sign an integrity declaration form online before they can access the problems, and they will submit the scans of their work on paper to get any credit at all. The author has also based grading on the work on paper more so than the submission online, as the rounding issues or simply mistyping a number will not be taken points off. This alleviates the anxiety of the students when they are worried if their answer format complies with the automatic grading of the online quizzes. With the scans, similar and strange mistakes on two or more submissions are easy to spot, which are also recorded evidence for integrity investigation.

Student Survey Results

Student surveys from these years (each with 14, 20, and 10 responses from various courses) indicated enhanced student engagement. The tradeoff is that time is needed for problem design, but these problems could be reused and allow automatic grading and customized feedback.

In Fall 2019 when Mastering was tried, the author did a survey in the middle of the semester. Despite their willingness to continue using Mastering in that course and potentially in future courses, when the students were asked if they would pay for Mastering, no one said yes, as shown in Figure 11. Table 1 has summarized student opinions regarding the Mastering platform. This was the driving motivation for the author to explore alternative approaches to implement multi-part problems with parameter randomization in LMSs.

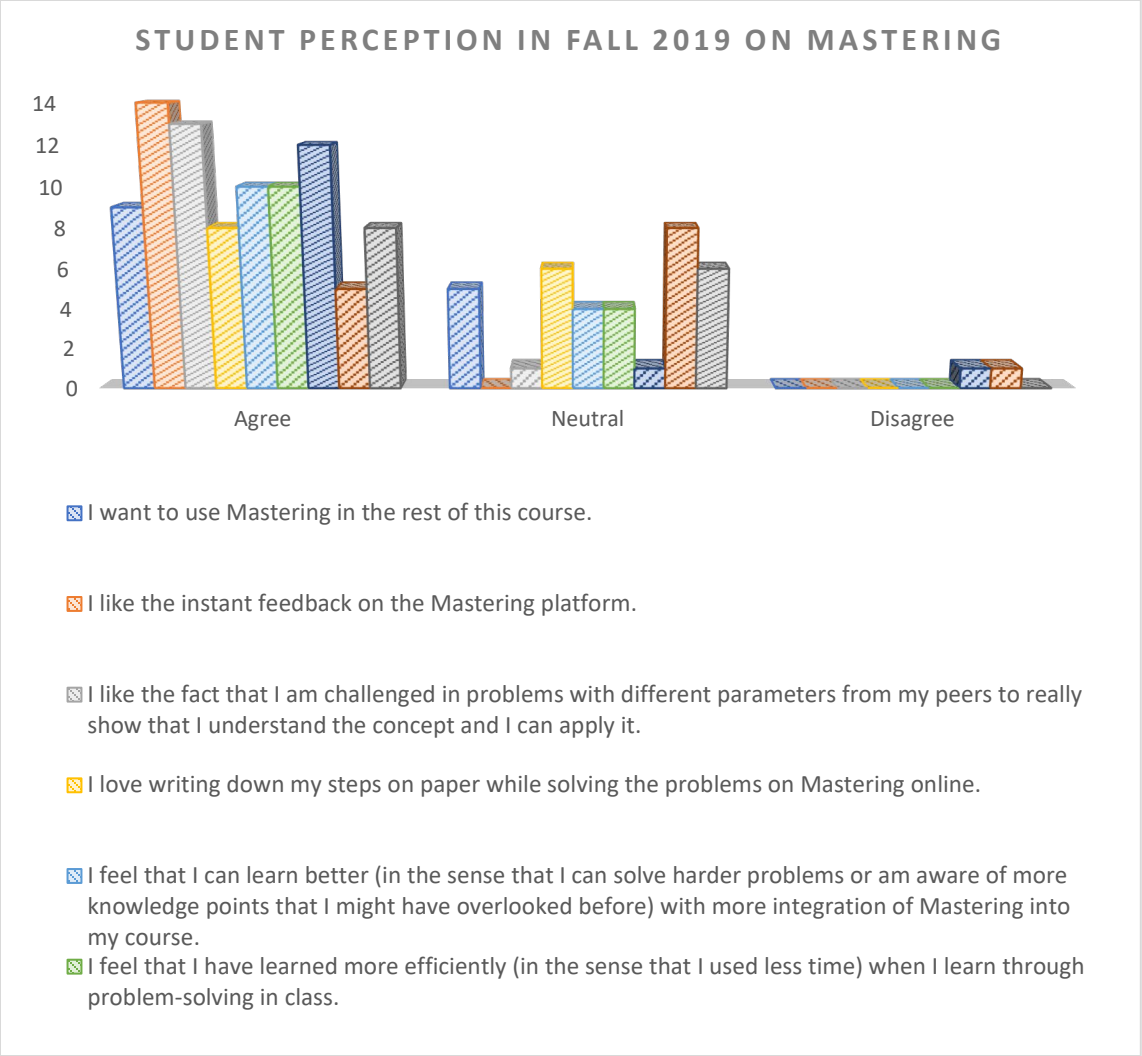


Figure 10. Student Perception of Mastering in Fall 2019

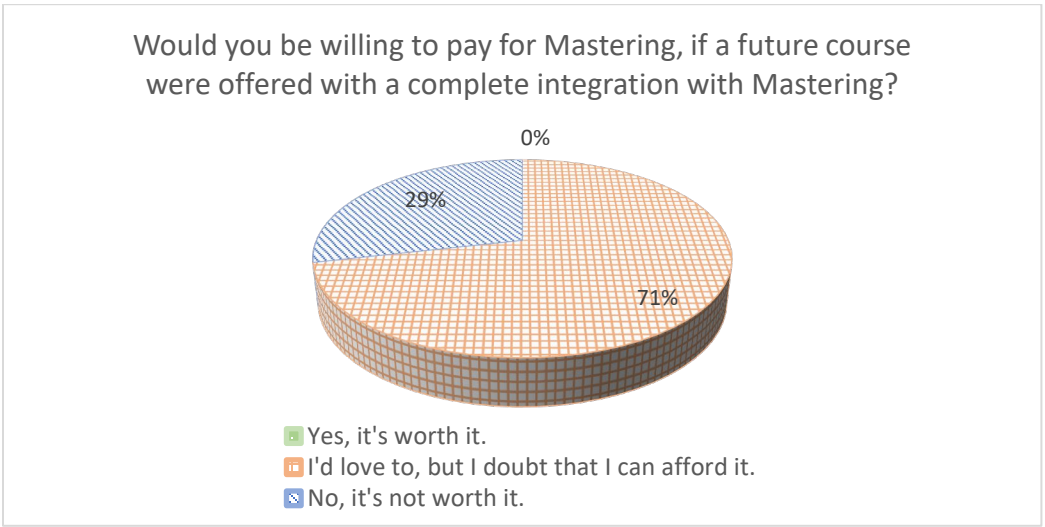


Figure 11. Student hesitation in purchasing Mastering in Fall 2019

Table 1. Student Opinions about Mastering in Fall 2019

What do you think is **working well** in using the Mastering platform?	instant feedback multiple attempts multiple choices allow one to see options easy to use
What **could you do better realistically** (not just some ideal that you don't really intend to do) to help you learn? Please answer openly and truthfully.	do example problems and check answers later perform calculations more carefully work on more problems outside of class be more aware and take time keep up with notes focus
What do you think is the **inherent drawback** to the Mastering platform that we just can't avoid? Can you live with it? Please answer openly and truthfully.	no partial credit attempts are limited hard to type an answer in the required format internet issues could cause trouble cheating online, including using Mastering e-book rounding error is annoying

When the pandemic hit in Spring 2020, these enhanced online quizzes became handy and important to keep engaging the students. A survey conducted on the students who have used such quizzes until Spring 2021 is shown in Figure 12. Some students said that they disliked the parameter variation to encourage them to do independent work, but that was exactly the purpose to keep them practicing independently. Some students did not care about the modality, while the majority liked the enhanced online quizzes.

While the students were still during the pandemic till about Spring 2021, their acceptance of the enhanced online quizzes shifted to regard them as "enhancing learning" more than "just an alternative", while they thought differently before the pandemic, as shown in Figure 13.

When asked about their preferences for test modality, the majority liked the online quizzes format, while some did not care, and a few preferred the paper test, as shown in Figure 14.

The students have also provided comments on what they liked and disliked about the online quizzes format.

Likes:

- I liked it personally since it encouraged me to do my own independent work.
- I liked the format of the online test because I was able to focus on one question at a time and not get anxious. I don't remember if we were given examples of how to write the answer in a certain format but that would be helpful on the test. I also liked the multiple parts because I didn't get confused on which step I needed to do first.
- They made me feel more confident about my understanding of the material and I felt prepared for the test.
- It is a great system that displays the type of knowledge the student has about the test, which I love.

- Having two attempts on the tests and finals was very nice to have. I also really liked how the instructor formatted the homework and quizzes with how you had unlimited attempts for the online part but you still had to submit your work for those problems to receive credit for the assignment. The online quizzes and homework format also made collaborative work easier whenever it was allowed.
- I appreciated that the online tests were able to be broken into smaller "tests" in order to better manage my time around other classes and projects. Especially around finals week with everything being hectic and due at the same time, it would have been more difficult to find a 4 hour block of time rather than multiple 45 min/ 1 hour time blocks.
- The exams were challenging but fair.
- Solving a complex problem in stages, knowing what the next answer is supposed to look like, really helped visualize the overall process.

Won't matter:

- The different parameters for each student is useful in an in-class setting as it encourages independent work. But in an online format such as during the pandemic, everyone is home alone so it wouldn't be necessary.

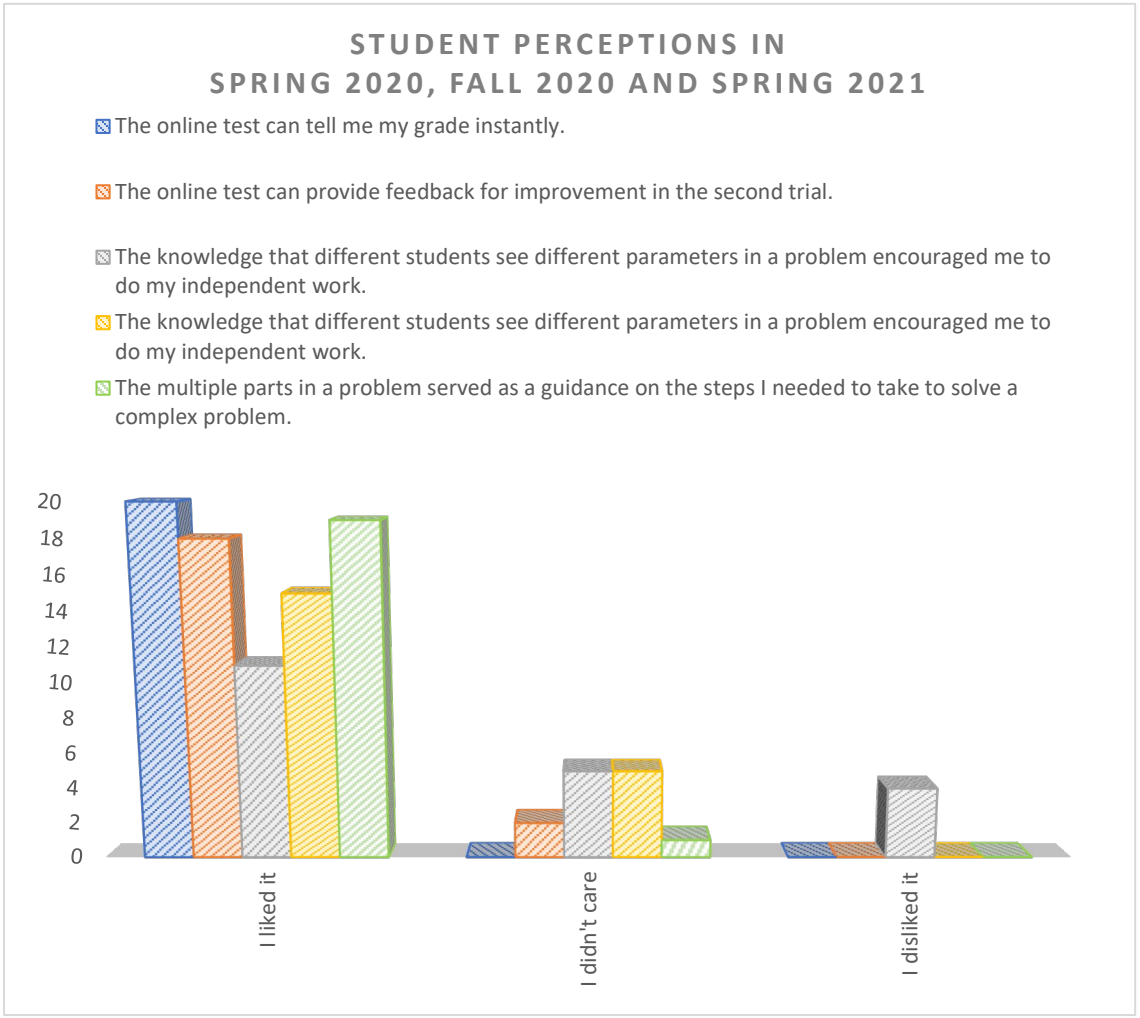


Figure 12. Student perception of enhanced online quizzes till Spring 2021 (during the pandemic)

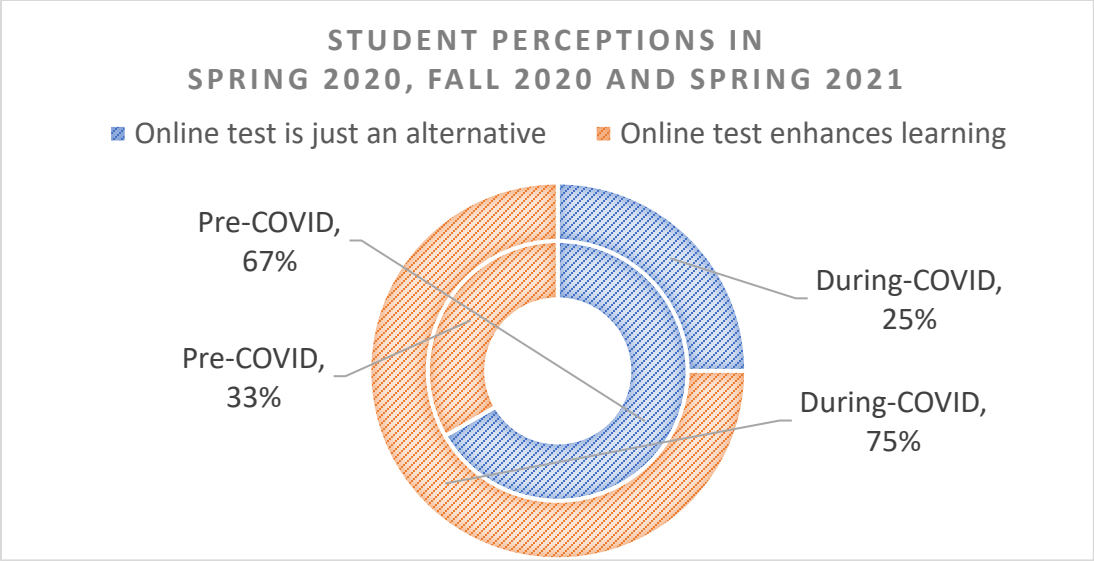


Figure 13. Student acceptance of enhanced online quizzes till Spring 2021 (during the pandemic)

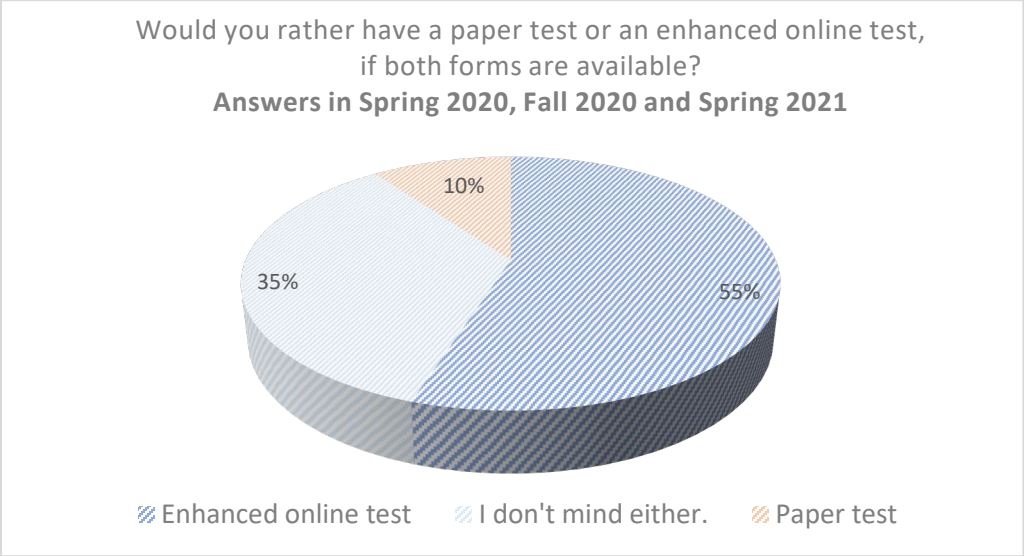


Figure 14. Test format preference till Spring 2021 (during the pandemic)

Dislikes:

- I enjoyed seeing my grade instantly but don't like how the answer could be marked wrong due to rounding errors. Timing of tests were more than adequate.
- The requirement to adhere to a specific format was problematic at times and resulted in at least one false answer that was actually correct...but that is the fault of the programming and not of the quiz itself.
- I disliked the formatting of questions that wanted problems solved in a very specific manor. I would prefer it if we were simply asked to solve the problem using whatever method we believed to be most suitable.

The same set of survey questions was administered to the students who used such enhanced quizzes in Spring 2022 and Fall 2022 when the pandemic was regarded as nearly abated. The comparable results in Figures 12-14 are presented in Figures 15-17.

The perception of the necessity of online quizzes has dropped to the pre-pandemic level, as shown in Figure 16. Note that Figures 12-14 and Figures 15-17 show the perception data from two different student populations, to reflect on their own past and current experiences. The results in Figures 12-14 are not a subset of the data in Figures 15-17 on the pre- and during-pandemic perceptions. Instead, Figures 15-17 show the second student population's perceptions of their past and current learning experience.

Despite the drop in perceiving the online quizzes to "enhance learning", when asked about their preference for test format, 100% of the students preferred the online quizzes format, as shown in Figure 17.

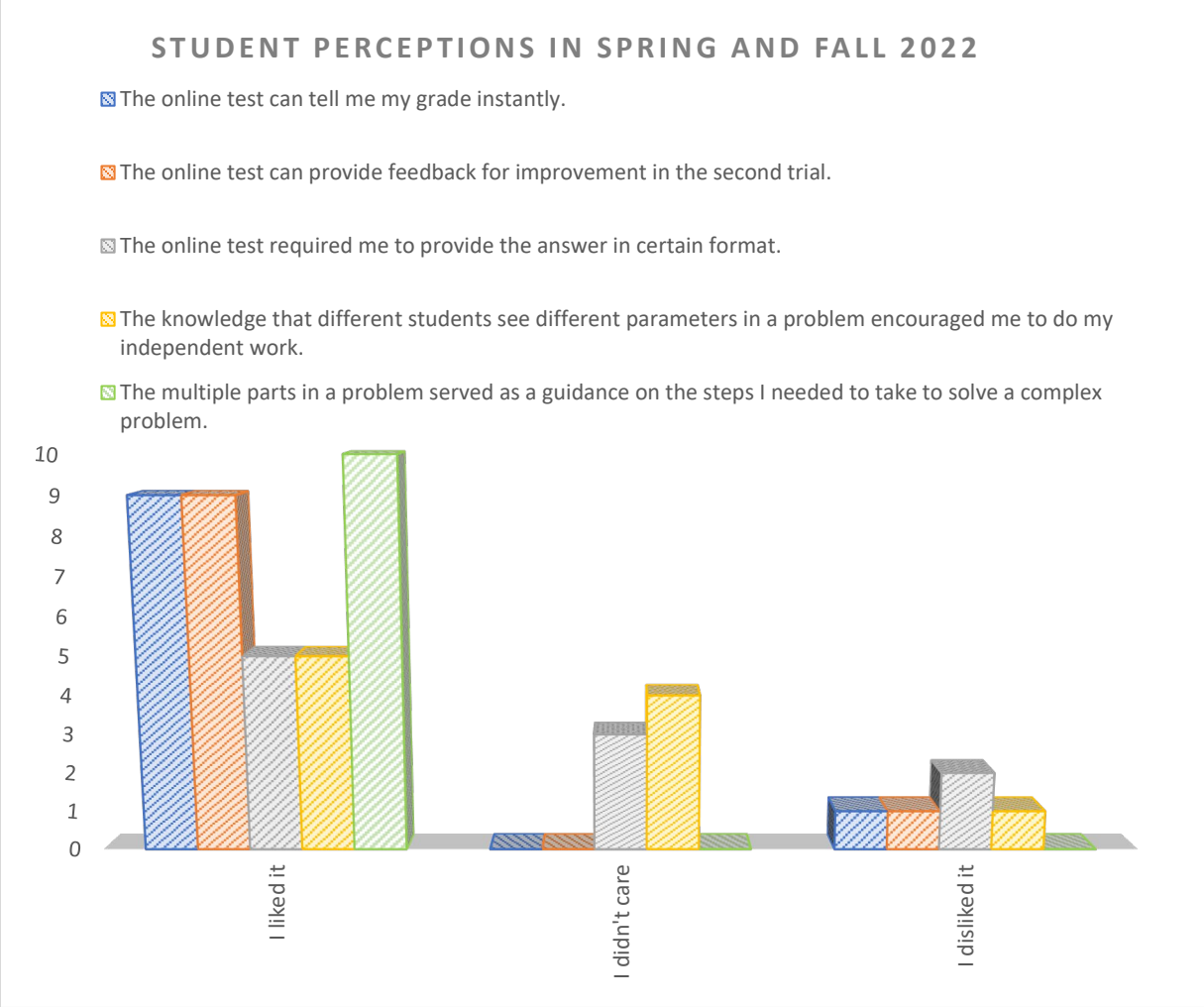


Figure 15. Student perception of enhanced online quizzes by Fall 2022 (post-pandemic)

The students in the post-pandemic survey group also shared their comments.

- The only issue I had with it was formatting where I believe I had the right answer but the

input digits were wrong or some basic rounding error happened. Maybe moving to more multiple-choice when there is a possibility of that would help some. Overall though I enjoyed the online aspect of the course and it helped my learning experience.

- Some versions of the problem were unexpectedly harder than others. As certain numbers resulted in easier and more straightforward work than others.
- I found online tests help is useful for providing good feedback, however, it just felt weird to me, but I can see how it was helpful for others.
- Canvas requiring precise answers instead of a range of values for math-intensive questions is baffling.

The pre-pandemic student group used Mastering, the during-pandemic student group used Connect and Blackboard, and the post-pandemic student group used Canvas, so some of their comments were specific to the platforms.

Canvas does not allow pattern matching or truncation in string matching as in Blackboard, so the author had to type a set of values to be all correct, but this set might not cover all the potential cases of student submissions, which created some frustration in the students.

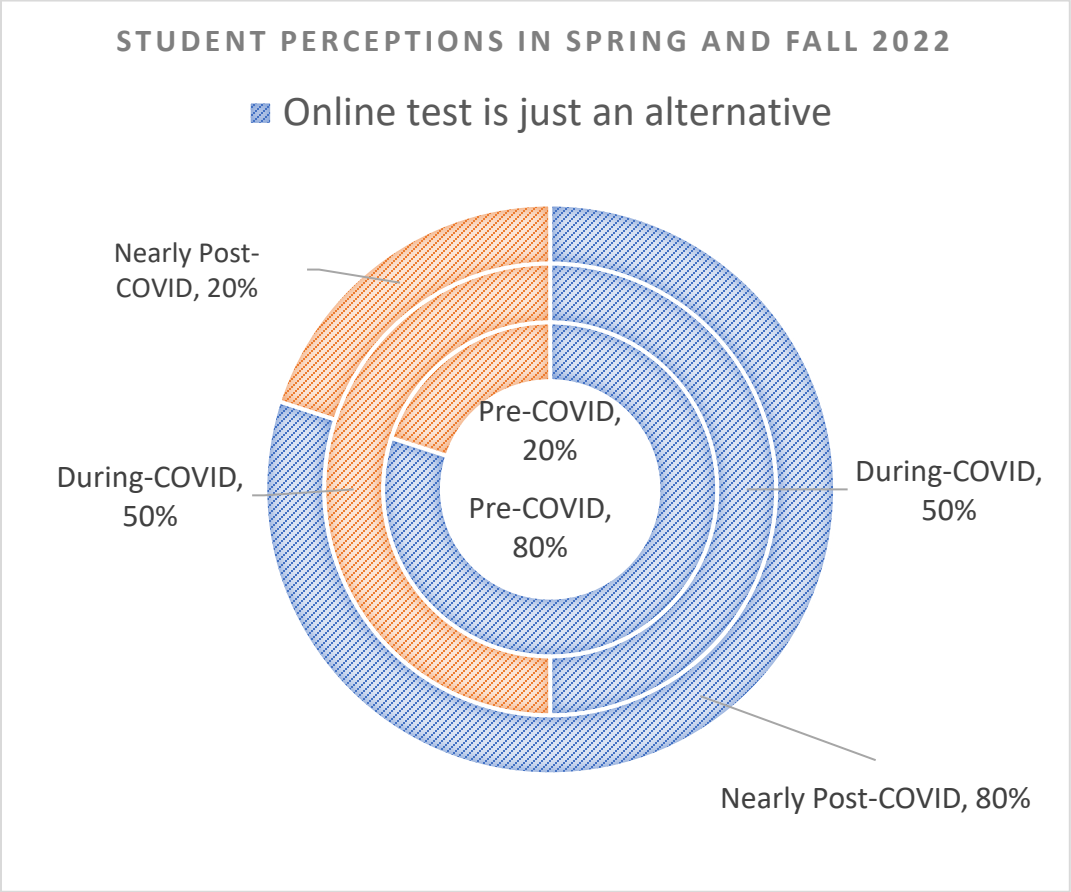


Figure 16. Student acceptance of enhanced online quizzes by Fall 2022 (post-pandemic)

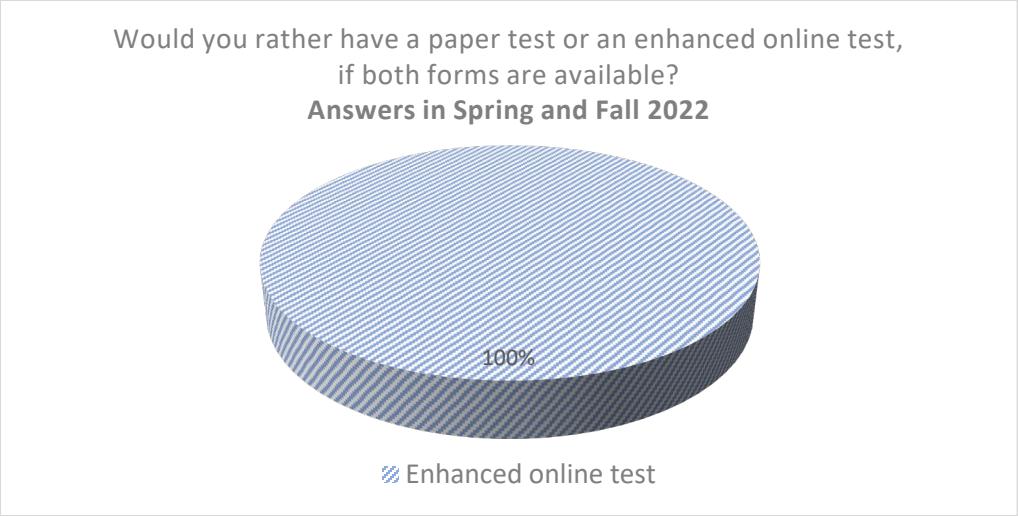


Figure 17. Test format preference by Fall 2022 (post-pandemic)

Regarding Figure 17, the overwhelming preference to use enhanced online quizzes, despite their perception of enhanced online quizzes as an alternative, may indicate other factors beyond enhanced learning. Students liked the second trial with some feedback (albeit not always accurate given the answer matching issue), less pressure in limited exam time, and the breaking down of the exams into sections, which could be continued in the future. Meanwhile, with ChatGPT and other AI-generated content, online assessments must consider plagiarism detection and student ethics education.

Student Grades Comparison Over Years

Besides student perceptions, student learning is the goal and metric of the effectiveness of adopting this approach. The student's GPA (Grade Point Average) may be influenced by many factors beyond this approach of using multi-part problems with randomized parameterizations. As a coarse overview of student learning, the average GPAs from two courses in four years are compared in Table 2 and Figure 18. The author did not teach other courses consistently to have comparable data therefore only these two courses are presented. Note that FA21 is omitted as the author was on sabbatical. The enrollment in "System Dynamics and Control" in SP19 was much higher than usual as students from two programs took it (Electrical Engineering and Mechanical Engineering), but we have since offered two separate courses for them. The later enrollments were only for Electrical Engineering students.

Table 2. Average Class GPAs in Two Main Courses in Four Years

		FA18, traditional	FA19, Mastering	FA20, Blackboard	FA22, Canvas
Circuit Analysis II	GPA	2.037222	2.4335	2.754211	3.237857
	Enrollment	18	21	19	14
		SP19, traditional	SP20, Connect	SP21, Blackboard	SP22, Canvas
System Dynamics and Control	GPA	2.6835	3.4505	3.384	3.5835
	Enrollment	45	32	33	22

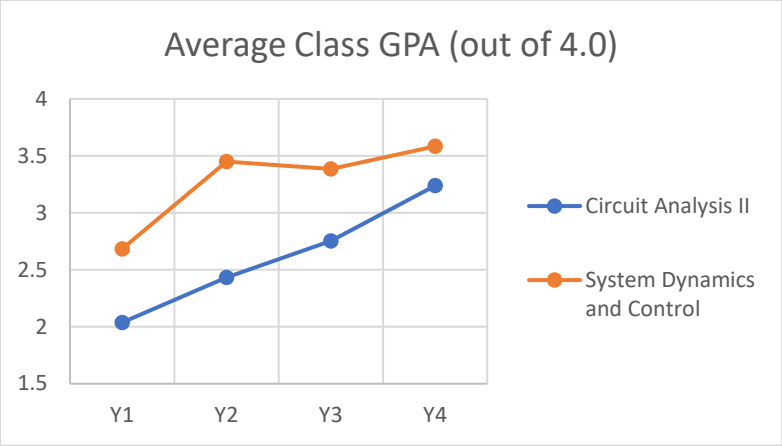


Figure 18. Class Average GPA in Two Courses in Four Years (Y1: traditional teaching without using online tests, Y2: Mastering or Connect, Y3: Blackboard adapted multi-part problem with randomized parameterization, Y4: Canvas adapted versions)

As seen in Table 2 and Figure 18, student performance has improved considerably in both courses, which supported the usage of multi-part problems with randomized parameterizations, although this approach might not be the only factor that contributed to the performance improvement. Note that several students who did not do well (C- or lower) on their first attempt repeated the courses the next year, where the second attempt might have helped their grades, as well. During the pandemic, the students could choose to use S (satisfactory for C or better) and U (unsatisfactory for C- and under) grades for several semesters. We do not know the original grades of the students with such S/U grades, so S is treated as C, and U is treated as F, when calculating the average class GPA, using the translation table in Table 3.

Table 3. Grade to Quality Points Translation Table

Grade	A+	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
Quality Points	4	4	3.67	3.33	3	2.67	2.33	2	1.67	1.33	1	0.67	0

Conclusions and Future Work

This paper first presented the desirable features of Pearson's Mastering platform and McGraw Hill's Connect platform in defining a multi-part problem with randomized parameterization, to support active learning. Then it described how to create similar features on the common Learning Management Systems (LMS) such as Blackboard and Canvas, using random problem selection in a question block or a question group. Blackboard accepts tab-separated CSV file upload to create a problem, and hence Excel is used to generate similar problems with different parameters for upload. Each row of the Excel sheet is an instantiation of the randomized parameterization of the problem, which is in the "Fill-in-multiple-blanks" type to allow the students to refer to the same set of parameters while taking the steps in problem-solving. The answer-matching criteria depend on the LMS, which is adjusted to allow a tolerance of calculation errors. Three groups of students were surveyed during the development of this approach: the first group was in Fall 2019 before the pandemic on using Mastering, which motivated the author to explore other alternatives without the price tag; the second group was

from Spring 2020 to Spring 2021 during the pandemic on using Connect and Blackboard, and the third group was from Spring 2022 to Fall 2022 post-pandemic on using Canvas. The last two groups of students reported their perceptions of the effectiveness of such enhanced online quizzes, their necessity, and which modality of the test they prefer. Despite some implementation and usage challenges, the students overwhelmingly preferred the enhanced online quizzes. The enhanced online quizzes helped engage students, especially during the pandemic, and they helped the students to get feedback instantly for active learning. The average class GPA from two courses where comparable data were available in four years supported the usage of multi-part problems with randomized parameterizations. With artificial intelligence-generated content (AIGC), more care needs to be taken to prevent plagiarism and ensure fairness.

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