Faculty Experience with a Novel Remote Testing Protocol for Online Courses

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***Abstract*— In this work, which is intended to be a Work in Progress Paper in the Research to Practice Category, a novel remote testing protocol based on Cognitive Load Theory and the Theory of Situated Cognition is described. The proposed protocol reduced students' cognitive overload during online exams by addressing student privacy, unreliable internet connections, accessible accommodations, all-or-nothing automatic grading, and false accusations of plagiarism. The described protocol relies on finite exam times and a sophisticated question randomization system. The protocol has been used successfully for five semesters, for two courses (20 sections).**

***Index Terms*— equity, MyOpenMath, plagiarism, remote testing**

I. INTRODUCTION

IN this work, which is intended to be a Work in Progress Paper in the Research to Practice Category, the faculty and student experience using a novel remote testing protocol are discussed. To reduce the debilitating effect of stress on student exam performance, the protocol was developed using Cognitive Load Theory (CLT)[1]. The central tenet of CLT is that the working memory of humans is limited and that when that working memory is exceeded, a student's learning and performance are degraded. A recent study explored the effects of extraneous cognitive loads on student performance in online courses [2]. Keeping track of each professor's proctoring system, managing the proctoring solutions [4], worrying about privacy [5,6], and dealing with technology issues takes cognitive resources from the student that would normally be spent on answering the exams questions.

While it is essential to reduce students' cognitive load, the Situated Cognition Theory (SCT) must be used to develop and administer realistic questions. SCT states that learning must be situated in the environment where the knowledge will be applied as closely as possible [7]. SCT has been used to develop technology-based courses [8], deliver realistic chemistry laboratory experiences [9], and create online education [10]. The protocol described in this work uses MyOpenMath, an online learning management system that can generate and automatically grade realistic exam questions.

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A remote testing protocol that reduces cognitive load, and provides realistic exam items, will not work if there is plagiarism. The Behaviorist Approach to learning [11] used by most faculty to learning is based on an accurate and fair assessment since plagiarism undermines any assessment system, the protocol designed to prevent plagiarism [12-19].

The first policy of the protocol is that each student has to take an "Honor Policy Quiz" that educates students about what plagiarism is and what behaviors are not allowed, given that made students do not know what plagiarism is [12]. These types of quizzes have been shown to prevent plagiarism [13,14]. Another plagiarism prevention technique is to make the exam have finite time and have the students take the exam simultaneously [15]. Another plagiarism prevention technique is using randomized parameters used in questions randomly pulled from a question bank [16]. In addition to these techniques, having professors proctor the exam can prevent cheating [17]. Another technique experienced online instructors use to reduce plagiarism is to make online assessments open resource exams or take-home exams that use items in which students are required to synthesize information [18-21]. Interestingly, experienced online instructors who prefer open-resource protocols do not recommend proctoring services.

Given all the constraints of administering online exams, the research question of this work is: Can a remote testing protocol be developed that reduces the cognitive load of the student that uses realistic questions? An essential condition of this protocol is that it must prevent plagiarism because plagiarism undermines measuring student proficiency to determine mastery.

II. METHODS

Since the risk reduction order from the governor in mid-spring 2020, all classes at the authors' institution were held online until the fall of 2021. The two classes from this study (five sections total) were synchronously delivered, and the exams mimic a face-to-face environment and have been described elsewhere [22,23]. The class size for each section was between 70 and 80 students. The protocol was used for five semesters. The authors' university is a Hispanic-serving institution with 90% first-generation college students.

The testing protocol relies on using the MyOpenMath learning management system (LMS) [24-28]. The MyOpenMath LMS is a fully functional LMS with sophisticated question delivery and an automated grading system. MyOpenMath can electronically deliver and grade questions with more than one answer, and questions in which a correct answer depends on a previous answer. In addition, MyOpenMath can grade questions based on a student's drawing. Finally, MyOpenMath can accept equations as answers. Questions in MyOpenMath are written in the PHP programming language, allowing for questions to be randomized in a hierarchal manner. MyOpenMath can be set up to plug into existing Learning Management Systems such as Canvas. For example, Canvas can control access to an assignment, call on MyOpenMath to deliver an assessment, grade it automatically and port the grades back into Canvas.

While not based on a learning theory, some things help manage the online instruction that the reader can find helpful. Zoom was used for lectures, and materials were prepared in PowerPoint or delivered using a Wacom tablet with the free smoothdraw drawing software, which Khan Academy uses. Each lecture is recorded and uploaded to YouTube for students to review. Lecture materials are available for reading before a lecture. In addition, notes are provided in google sheets with links to videos and other resources. Proving these notes is done so that students can access the class material after the learning management system is closed when the semester ends. To better organize the material so students can keep track of their progress, the Canvas shells are set up to have one module per class period, containing all the information for that class period. A standard Canvas shell is given to the instructors of a class which has been shown to reduce training time for new instructors. All instructors are trained to grades exams in a similar fashion.

A. Protocol description:

1) **Overview of the Testing Procedure**

Prior to the exam, students take an **Honor Policy Quiz**. Students are encouraged to enter the zoom session 10 minutes before the start of the exam. Students log into Canvas and download and save a copy of the MyOpenMath generated exam from Canvas (**Exam Delivery**). The exam questions are **Randomized**, and the **Allowed Resources** are an open book and open note. The **Finite Exam Time** is controlled with Canvas. The students enter their answers in MyOpenMath and upload a scanned copy of their work to Canvas (**Exam Submission**). The professor grades the scanned exam (**Grading**)to ensure students showed their work and verify the students have no incorrect answers accidentally entered into MyOpenMath. The **bolded** items are discussed in the following sections.

2) **Honor Policy Quiz**

Students take an online honor quiz that educates the student about what behaviors constitute plagiarism, which consists of answering two questions in the affirmative:

1. I agree that I will neither give assistance nor receive assistance from others to answer the questions on midterms or exams in this class.
2. I understand that I can use the book, my notes, Canvas resources, or non-interactive internet resources to take this online midterm or exam.

3) **Exam delivery**

Exams are delivered with MyOpenMath, which selects random problems with random numbers for each type of question. Each question type has its own question bank. Care is given to ensure that the delivered problems from each question type are of similar difficulty. Sample question types are deriving the Thevenin equivalent of a resistor indictor capacitor (RLC) circuit, deriving the transfer function of a circuit content an operational amplifier, drawing Bode plots, and designing feedback networks for system stabilization.

4) **Finite-Time**

Students have a fixed time to take the exam to prevent communication between students taking the exam. The reason to have a finite time is due to the fact that learning objectives are designed to be individually met and not collaboratively met. The time is controlled by the "available from" and "until" due date functions in the assigned block of a Canvas assignment. The students get the regular face-to-face time to take the exam, plus an additional 15 minutes to scan and upload their exam to Canvas. Students with a time-extension accommodation are given extended "until" times. Students are instructed to save a pdf copy of the exam before starting to answer questions.

5) **Randomized Questions**

The exam problem bank had a sub-section for each concept to be accessed, with several styles of questions in each subsection. Each question was further randomized with realistic design constraints or circuit parameters. The randomization was done so that each student could be guaranteed a unique exam, which prevented unauthorized cooperation, which was detected at the authors' institution in courses that only used the Respondus lockdown browser as a deterrent. Since preventing plagiarism is more efficient than detecting and prosecuting it, randomization of questions is required. In face-to-face exams, all students received the same exam questions, and the instructor prevented unauthorized cooperation because the class size was kept to less than 80 students.

6) **Allowed Resources**

Students are permitted to use any resource to take their exam, except interactive resources such as friends, family, other professors, or live homework help sites. The word interactive was chosen because artificial intelligence systems might help students take exams at some point in the future. Published solutions from internet sites such as Chegg are allowed but discouraged. Allowing an open-book open note style of exam reduces student anxiety and thus the student's cognitive load. It is also more efficient than trying to monitor students during the exam. Finally, open resource exams are more realistic and thus follow the situated cognition approach.

7) **Exam Submission**

Students enter their answers into MyOpenMath and then upload an electronic copy of their work into Canvas. If students do not have an electronic device on which they can write their answers, they print the exam using a printer and write their answers on the exam. If the students do not have a printer, they write their answers on blank pieces of paper. The students save an electronic copy of their work or create an electronic copy with a scanner, and then upload it to Canvas. Students are given 15 minutes to upload their exam to Canvas to balance reducing the cognitive load due to the stress of uploading an exam and preventing plagiarism.

8) **Grading**

In the introduction to circuit analysis course, all problems are automatically graded by the MyOpenMath system. In the circuits and systems course, most questions are only delivered by MyOpenMath. In both cases, the scanned and uploaded exams are either graded or reviewed by the professor to ensure that the students did the work to get the answer and to ensure that students are not harshly penalized for typos. The fact that the professor will review students' answers reduced the student's cognitive load by taking away the worry of accidentally entering in the wrong answer into MyOpenMath by mistake (typos).

9) **Exam environment**

Students log into zoom and Canvas before the start of the exam. Students are encouraged to turn on their cameras, but if there is an issue with the camera or privacy concern, they can keep it off. Students can leave the exam's Zoom session after they have uploaded their answers to Canvas. Students are muted and advised to ask questions in chat only so that other students are not distracted. Students are told not to discuss the exam until they receive a message from the instructor that the exam is over for everyone. This turns out to be an important message because, in other courses in the authors' department, some students pretended to be done and were able to concince other students into giving them unauthorized exam answers.

10) **Other Policies that reduce the effects of cognitive overload**

a) **Technology: Internet Issues**

Even though our syllabi indicate the computing/networking requirements needed to participate in the course successfully, every effort is made to accommodate those students who do not have the resources to avoid equity issues [29,30]. Students are instructed before the exam start time to email the instructor if there are internet problems during the exam, keep working on the exam, and create a electronics copy of thier work with a timestamp showing that it was completed before the due date (adobe scan). Usually, the internet does not stop working altogether. The most common issue is that high bandwidth applications stop working. If a student forgets to input their answers into the MyOpenMath system, the instructor grades the scanned copy of the work. If a student only answers the questions in MyOpenMath, the grade from the MOM system is used.

b) **Technology: Zoom discussions, chat**

Students have a heightened sense of awareness (increased cognitive load) due to the high-stakes nature of university exams. Students are encouraged to ask questions in direct message chat rather than asking questions aloud to mitigate this heightened awareness. In other words, the student's cognitive loads can be affected by other students' cognitive loads. For example, suppose some students ask too many questions out loud. In that case, other students will start to doubt themselves and ask the same question repeatedly, or some students will find a new way to misinterpret instructions, leading to a large-scale panic. This behavior can happen even in when students only use group chat. The instructor has to keep calm and state in a calm voice that everything will be ok and that the students will not be penalized for typos or not following the protocol strictly to avoid this panic.

11) **Sample Questions**

To give example of the realistic type of questions asked in these two courses, sample questions are presented along with information on how questions randomization occurs.

a) Sample System Stability Question:

The following transfer function is out of control:

$$H(s) = \frac{b_i s^i}{s^2 + a_1 s + a_2} \quad (1)$$

The variables s, is the complex Laplace transform operator, and the and b constants are the real variables that describe the system. The variable i is an integer that controls the order of the system in the denominator. Students have to explain why the system is out of control, design the simplest feedback transfer function G(s) that will make Q(s) stable, and state the conditions on the constants of G(s) that will ensure that the system is in control.

To randomize the question, i is an integer from 0 to 2, and a_1 and a_2 are integers that can be negative, positive, or equal to zero. To ensure that the system is not stable a_1 and a_2 cannot both be greater than 0. To keep the questions, similar a_1 and a_2 cannot both be equal to 0.

b) *Sample Bode plot question:*

Students draw asymptotic magnitude and phase frequency responses of an overdamped second-order low pass or high pass filter with real roots. Ω1 and ω_2 give the break frequencies in radians/s. Equation 2 represents a low pass filter, and equation three represents a high pass filter.

$$H(s) = G \times \frac{\omega_1 \omega_2}{(s+\omega_1)\times(s+\omega_2)} \quad (2)$$

$$H(s) = G \times \frac{s^2}{(s+\omega_1)\times(s+\omega_2)} \quad (3)$$

The G (Gain) factor is randomly chosen from 1, 10, or 100. The cutoff frequency is chosen randomly to be equal to each other, two orders of magnitude different from each other, or three orders of magnitude from each other. The lowest cutoff frequency is randomly selected from 10 or 30 radians/s to make it easier for automating grading to recognize correct answers. While it is possible to have MOM automatically grade this drawing, one has to set the acceptable tolerance to a large value so that answers that are close to being correct are marked correct. As a result, students can get points for not drawing anything. These problems will always need some form of manual checking.

c) *Sample Circuit Schematic Question:*

Students are given a transfer function for a linear time-invariant (LTI)system shown in equations 4 and 5, representing either a 4'th order Butterworth bandpass or a notch filter. The students have to draw the schematic (Operational Amplifiers (OPAMPS), capacitors (C), and resistors (R) that will implement the transfer using the state-space architecture. They do not have to calculate resistor and capacitor values, but all the parts and connections must be correct and properly labeled. Students are reminded to ensure that they label the output node.

$$H(s) = \frac{b_3 s^3}{s^4+a_1 s^3+a_2 s^2+a_3 s+a_4} \quad (4)$$

$$H(s) = \frac{s^4+b_2 s^2+b_4}{s^4+a_1 s^3+a_2 s^2+a_3 s+a_4} \quad (5)$$

The a and b constants are calculated from the Butterworth condition from a randomly selected frequency response.

d) *Sample OPAMP derivation question:*

Assume the OPAMP is ideal. For the circuit shown below, Resistance (R)=44kΩ, Inductance(L)=5.6mH, and Capacitance (C) =72.4pF. The voltage source V_{in} is a 7-volt step input at time=0s.

Is the circuit overdamped, critically damped, or underdamped?

What is the current through the capacitor long after the change in Vin at time=0s?

What is the voltage, Vo a long time softer the change in Vin at time=0s?

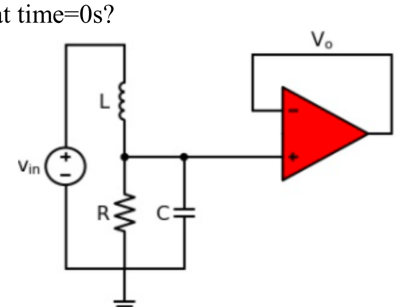

Fig. 1: Low pass filter example

The question is randomized by choosing a bandwidth randomly from 50kHz to 250kHz in steps of 50kHz. The value of the inductor is set to a realistic value of 5.6mH, and the value of C is calculated from the bandwidth. Finally, the resistor value is calculated based on randomly choosing if the circuit is over, critically, or underdamped, based on a damping coefficient ζ of 10, 1, and 0.1, respectively. There are several RLC filters configured that can be randomly selected as well.

B. *Student Feedback:*

Students were asked their opinion on how to improve the remote testing protocol. There were asked five questions:

1. Which course are you enrolled in?
2. Please describe the things that you appreciate about the implementation of the remote testing protocol.
3. Do you think that this exam protocol could be changed to a "take-home" exam and still prevent cheating?
4. How does the protocol compare to other systems/tools such as Respondus lockdown browser, Proctorio, or even "take-home exams"?
5. Please describe the things that you think could be improved with implementing the EE98/EE110 remote testing protocol.

The questions were sent to one section of the Introduction to circuit analysis course and one section of the circuits and systems course in the spring of 2020. Out of 140 students who were enrolled 19 students responded. Students were invited to give their feedback anonymously with a non-leading prompt, asking them for help with the protocol. These questions were only screening questions and not a fully developed assessment instrument.

III. RESULTS AND DISCUSSION

There have been no detectable instances of plagiarism using this protocol. There is a recurring problem of students using incorrect Chegg solutions, however. Even if this is not plagiarism according to the protocol's policy, faculty feel that students who use Chegg are "cheating themselves." The use of Chegg occasionally happens despite a warning about how Chegg solutions are not verified. Some unaffiliated instructors state that they post incorrect solutions to their assignments on Chegg (Plagiarism thread on MyOpenMath site). This is rare, and the time saved by not having to invest claims of plagiarism is significant. There is a considerable time cost in proving a sanction such as an F in an assignment is justified.

Plagiarism was prevented using finite time and randomized questions, so the effort to administer the exam according to the protocol was justified. The time saved by not having to invest claims of plagiarism was significant given that a considerable time cost in proving a sanction such as an F in an assignment is justified.

In the first semester, the protocol was used for the second and final exams. Student grades went down in all sections when the second midterm format was switched from a face-to-face exam with an instructor-provided equation sheet to the proposed online exam protocol. While this must be due partly to the pandemic, some students were lured into a false sense of security when taking an open resource exam. Students were taught how to create their study sheets and prepare for an open-resource exam to mitigate this. The exam scores increased on the final exam, but the passing rate remained low when comparing online to face-to-face course delivery.

It takes significant effort to learn the MyOpenMath question generation language, which is based on PHP. It takes even more effort to create and maintain randomized items: this effort recovered in time to save grading and exam creation. Courses like an introduction to circuit analysis and circuit and systems courses naturally have items that can be randomized but still have realistic questions. Courses that deal with advanced topics might be hard to generate randomized items. In advanced courses, the content changes so rapidly that the time cost in item generation is not recouped by automating exam generation/grading type tasks.

One issue with the method is that the instructor must be present for an extended time due to accessibility accommodations. Under face-to-face conditions, our Accessibility Resource Center provided the proctoring services required for extra time. In addition, students with an accommodation should schedule their exams around their other classes. In this remote learning environment, students have to take the exam simultaneously as the rest of the class, and as a result, their accommodation time extends into their following lecture. Services like Proctorio would allow more flexible exam scheduling. These services are expensive, and the more they are used, the less money there is for other things. Post pandemic budgets might not allow for these services.

It seems that the method of changing the wordings of items does not reduce the use of sites like Chegg. While this is not considered plagiarism in this protocol, those using the websites do not do as well. The students are provided with all lecture materials. Interestingly, they will use unverified sources rather than the notes and provide exam solutions provided by the instructor. It could be that these courses present so much information in Canvas, which does not seem to be searchable, that when a student is lost, they just search for the answer any way they can, and paid sites are returned on top. It might be possible to put notes in google docs and slides and then publish them to the web feature. Still, it would be much better for students to prepare their study guide for the take-home exam.

Since MyOpenMath automatically grades the exams, it allows the instructor to randomize each question, discouraging students from cheating. MyOpenMath provides valuable information, such as how much time students spend on average on specific topic questions. The instructor can use the tool to educate students on managing their time while learning their strengths and weaknesses on different questions. For example, some questions may trap students even though that may not be the instructor's intention. After the exam, the instructor can review the student's work on a one-on-one basis and give constructive feedback on how the student is doing on each question compared to the other students. For example, based on the time spent on each question and points earned per question, the instructor can suggest an individualized study guide to help the student for the rest of the class. Also, the instructor can help the student improve time management and avoid traps on each question based on the complexity of the problem.

Online testing makes students extremely nervous. MyOpenMath automatically grades the answers based on the final result in each step. Correct answers may depend on the previous ones if a question has multiple parts, such as applying superposition to a linear circuit. If the student makes careless mistakes such as not using the right sign or some mathematical errors, they may lose many points on that question. Of course, if the instructor does not believe in giving partial credits, it would devastate the student. The other painful option is for the instructor to read every single solution and apply partial credit to each of them if applicable. The problem with this method is the total number of questions an instructor has to grade. Let us assume that each question group may have ten random questions. In a final exam for fifty students with ten questions, the instructor has to grade 500 different problems.

Making each question in a group of questions to be similar is very challenging. One of the complaints was that the complexity of the work was not the same. For example, some problems may have different solutions; for instance, some may require taking derivatives, while some may require taking an integral. Typically, students feel that taking integrals is less trivial than taking derivatives. Students who had to take integral may think they were more disadvantaged than the group to get away with taking derivatives.

Student Feedback: 19 students responded to the survey, with 58% identifying as being enrolled in the circuits and systems course and 42% identifying as being enrolled in the introduction to circuit analysis course.

Feedback 1: Five students felt a stress reduction due to not using the lockdown browser. Two students mentioned that they appreciated the privacy afforded by the protocol.

Feedback 2: All students prefer this work's protocol when compared to other in-class exam protocols.

Feedback 3: 63% of the students felt the protocol could be adapted to a take-home exam format.

Feedback 4: Some students felt that it would be better to schedule the exam outside class time because they did not have a quiet place to take the exam. Two students felt that the questions were not all equal difficulty.

While the response rate for the survey was low, it is typical of survey response rates where no reward is given. The survey helped make sure that there were no hidden issues in administering the protocol.

A preliminary regression analysis was performed that compared the student's pre-requisite final grade of the Introduction to Circuit Analysis (ICA) course to the midterm 1 grade of the Circuits and Systems (C&S) course with two groups, those who ICA course followed the protocol (n=20) and those that did not (n=36). While both groups found a significant relationship between the ICA pre-req grade and the C&S midterm grade of less than 0.05, the R^2 value of the protocol pre-req group was 26 while the non-protocol pre-requisite group was 12. In addition, the protocol pre-requisite students outperformed those who did by an average of nine points out of 100. The standard deviations were 27 and 30 for the protocol pre-req and non-protocol pre-requisite respectively. This analysis did not include other factors that might be influence student performance. Multiple instructors (three) for the ICA pre- requisite course contributed students to the protocol pre-requisite group.

IV. CONCLUSION

A protocol based on CLT and SCT was used for five semesters. While student performance decreased compared to face-to-face instruction, a testing protocol was developed that reduced the student's cognitive load using realistic questions. This protocol prevented plagiarism, and measured student proficiency to determine mastery in a practical manner.

Future work might be to make the exam collaborative [31,32]. This could lower anxiety induced cognitive over load.

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