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Student-designed Assessments in Electrical and Computer Engineering: From Student Perceptions to Their Mastery of Materials

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Abstract

The remote model of instruction, after the pandemic, highlighted the need for creative and versatile assessment methods in engineering education. Developing authentic methods of assessment with the potential to reinforce mastery of the materials through channels other than learning by preparing for the tests was of particular interest. One such method that we selected was student-designed exams. Developing well-designed engineering problems requires a mastery of the material, so we put students in charge of designing their exam problems to help them achieve a higher learning level. Students also participated in follow-up one-on-one meetings with an instructional team member, after each assessment, to receive feedback and answer questions related to their designed exam problems. Using the student-designed exams as an assessment method could offer other benefits, such as reducing academic integrity violations, since each student designs a unique test and submits the solutions to their designed questions. This assessment method was also helpful in reducing the anxiety associated with high-stakes tests.

In this paper, we explain the implementation of the student-designed exams in an Electrical and Computer Engineering course at the University of California, San Diego. We also discuss the format of the follow-up meetings, the grading scheme, students' perceptions of this assessment method, and the instructor's findings regarding the effectiveness of this intervention. In the feedback surveys, students mentioned that designing exam questions pushed them to pay more attention and master the concepts. They also reported that the follow-up meetings were beneficial in clarifying the confusing points and correcting their mistakes.

Introduction

This study focused on the implementation of a new assessment method in an electrical and computer engineering course during remote instruction. For this assessment, students were asked to design problems at a cognitive level similar to the problems solved in the class and the past exam problems, relate their problems to the course's learning outcomes, and rate their problems' cognitive level. They were required to submit both the self-designed problems, and their solutions to those problems. Designing exam-level problems requires a mastery of the material. The exam givers should have an in-depth understanding of the concepts to develop problems that could assess the achievement of learning outcomes. This new assessment method was intended to provide students with an opportunity to participate in designing exam questions and hence achieve higher learning levels. To further facilitate the achievement of this goal, students attended 15-minute follow-up meetings after submitting each question set. The follow-up meetings were one-on-one meetings between students and an instructional team member. In these meetings, the Instructional Assistants (IAs) or the Professor provided feedback to students on their designed problems and discussed the submitted solutions with the students.

The course that we selected to implement the new assessment method is a math-intensive course related to continuous-time and discrete-time linear time-invariant systems and analyzing such systems using Laplace and Fourier transforms. Both junior and senior level students enroll in this course every quarter. The new assessments were added to the summer 2020 offering of the course, while the spring 2020 offering of the same course was used as the control course. The course was offered in a fully flipped classroom style in both spring and summer sessions. The only difference between the two offerings of the course was the addition of the new assessments to the summer course. Students were required to watch a pre-recorded lecture video and take a related multiple-choice reading quiz before attending each synchronous class session. During the lecture, students participated in think-pair-share activities and solved a few problems selected by the instructor. Students had access to those problems ahead of time. A set of few MATLAB assignments were also used in the course in both sessions.

In this pilot study, the potential of our new assessment method in helping students achieve mastery of the materials is explored. A comparative analysis of how students rated their designed questions' cognitive levels and how the course instructor rated those problems is provided. Other benefits of the new assessment method, including its potential in improving the integrity of the tests, are discussed. Feedback survey results are used in analyzing students' perceptions of their learning. The results of these surveys were in agreement with the instructor's findings and reflections.

Literature review

This literature review will contextualize the present study through a review of scholarship on self-directed learning, student-designed assessment, and emergent literature on assessment design during emergency remote instruction due to the pandemic.

Self-directed learning

Self-directed learning is a pedagogical approach that provides the opportunity for students to design, execute and assess their own learning. A common misconception is that self-directed learning can only occur in isolation from all other input from either the educator or fellow students. Students can work in a highly self-directed way while being a part of a larger team. Notably, a salient trend in the research suggests that students with highly developed self-directed learning skills connect and consult with a range of peers and leverage their learning network to make their choices about the direction of their learning [1].

Foundational literature that examines the construction of a successful self-directed learning environment suggests that learning should reflect three distinct parts: The learner, the educator, and the learning resources [2]. Significant parts of this model see the educator as providing the environment and resources for students to practice and develop their self-directed learning skills as opposed to directly instructing the student in the process. The learner is then able to make decisions about their learning, explore and experience in a guided environment and reflect upon what supported their knowledge and comprehension of the material [2]. Recent literature posits that students with highly developed self-directed-learning skills were able to achieve three

indicators of problem-solving ability. Notably, the ability to understand mathematical problems, create learning pathways to solve these problems, and implement a defined learning strategy plan correctly [3]. Conversely, findings are reported in the literature that indicates students with moderate and low self-regulation are challenged when solving problems and struggle with applying learning strategies that support their knowledge and comprehension of the material [3]. Further, the merits of self-directed learning strategies for engineering education are evident in the literature and correlate with student goal setting [4], developing empathic skills as an engineer [5], and finally building resilience to meet the challenges of this profession [6].

Self-directed learning & assessment

Furthermore, emergent themes in the literature are the way in which self-directed learning and assessment are vital for student success and enhancing critical thinking skills. Findings indicate that when students are provided the opportunity to self assess their work, reflect upon their learning, and incorporate feedback from their peers, this process has a cumulative and recursive effect on students' thinking, actions, and feelings [7]. Analogous to this is a framework that addresses learning-oriented assessment. The framework focuses on three core components: assessment tasks that stimulate sound learning and learning practices among students; the active involvement of students in their learning through engagement with criteria, the recognition of quality and evaluating their own and/or peers' performance; feedback which is timely and forward-looking so it supports current and future learning [8]. Overall, the findings suggest that it is the interconnected parts of this framework unified as a whole that has a statistically significant impact on student learning [8].

Student-designed exams

Student-generated exam questions as a specific type of student-led formative assessment have been consistently studied in the literature. Research suggests that there are multiple potential benefits that arise from asking students to generate possible exam questions, including improvements in performance on summative assessments and overall course grades [9]–[14], the bank of questions functioning as a useful study aid [11], [15], encouraging higher-order cognitive skills through peer review and discussion of questions [10], [14], [16], [17], and increasing student engagement in the process of assessment, as well as the course in general [9], [12]. Research has also found that students perceive this form of assessment as worthwhile for their learning [14], [17]–[19], even if they sometimes report a lack of confidence in the quality or cognitive complexity of student-generated questions, as was also found in the present study [10].

Previous studies of student-generated exam questions have generally focused on methods using peer discussion of questions, where students solve through and critique one another's questions [9], [10], [16], [19]. Some studies are also reported in which a portion of a subsequent summative assessment included a few student-generated questions chosen by the course instructors [14], [15]. In the present study, students fully generated and solved their own exam questions individually, in effect both creating and answering their own exam. Although the testing effect - based on retrieval of information from memory - appears to benefit learning [20],

[21], tests also generate significant anxiety for students [22], [23], and reviews of the literature have found that the act of generating questions in itself can be beneficial for learning [24]. Rather than focusing on generating a test bank for a general exam, the present study hoped to investigate whether this approach could still benefit students while reducing test anxiety.

In part, the approach of asking students to create and solve individual exams also arose from the impact of the COVID-19 pandemic on assessment practices. Many instructors turned to new assessment techniques in response to the challenges that the COVID-19 pandemic posed in ensuring academic integrity in the remote learning environment, particularly with traditional multiple-choice, timed exams [25]–[27]. Early evidence suggests that open-book assignments, such as the one studied in the present course, did not yield more academic integrity violations as an alternative assessment method than traditional, invigilated exams when given under reasonable time constraints [28]. A previous study of student-generated exams also found a very low incidence of plagiarism in student-submitted questions, with only 2 out of 524 analyzed questions being copied directly from another source [17]. In the present study, a highly individualized, open-book form of assessment was chosen not only for its potential benefit to student learning but also its potential to contribute to the integrity of assessment in an emergency remote learning environment.

Another feature of this study that differed from previous approaches was the inclusion of individual follow-up meetings with instructional staff in which students discussed their self-generated exam problems with the instructor or a course TA. This type of informal interaction with faculty in settings like office hours has been found to be beneficial for student learning and motivation [29], [30]. Additionally, these meetings provided an opportunity for students to receive feedback on their performance after solving the exam problems. In a study involving feedback given on exam performance, providing this kind of explanatory feedback was found to increase learning in comparison to simply providing the correct answer [31].

Overall, this study sought to leverage and combine the benefits of several evidence-based strategies (student-directed learning and assessments, open-book assessments, and informal instructor-student interactions) to advance understanding of new models of assessment for engineering education.

Methods

This study was conducted at UC San Diego, a large public research university in the United States. The course, Linear Systems Fundamentals, is usually offered every quarter and in summer in the Electrical and Computer Engineering (ECE) Department at this university. The data from the spring and summer 2020 offerings of the course is used in this paper. In spring, the course was taught in two weekly 80-minute class sessions, and in summer, it was taught in 80-minute sessions four days a week. The same instructor taught the course in both sessions. In the spring quarter and summer session, 186 and 57 students enrolled in the course, respectively. Both classes were conducted remotely through Zoom. Although the majority of

enrolled students were seniors, in both terms, junior and sophomore students also enrolled in the course. Table 1 shows the breakdown of students by year in the program.

Term	1st year	2nd year	3rd year	4th+ year
Spring 2020	0	4	71	106
Summer 2020	0	2	6	49

The course was offered in a flipped classroom format in both spring and summer sessions. Students watched pre-recorded lecture videos and responded to multiple-choice reading questions before attending the synchronous class sessions. In the class, they practiced solving example problems and completed some MATLAB activities. Both courses were offered online, and MATLAB online was used for the in-class MATLAB activities. Assignments in both classes consisted of 4 MATLAB projects that students completed during the quarter. In the spring quarter, the midterm and final exams counted for 25% and 30% of the total course grade, respectively. Both exams were in the format of take-home tests. In the summer session, the midterm exam was replaced with the new assessment with 25% of the total course grade. The final exam counted for 35% of the total course grade and was also in the format of a take-home test.

The new assessment used in the summer course consisted of four sets of student-designed questions. Since the summer session was a 5-week long term, students submitted one set of these questions every week starting from week 2. For each question set, students prepared 5 to 10 problems related to the topics covered during the week. Students were given the option to use the lecture notes problems or the textbook problems for inspiration, but they should have modified those problems to generate new questions. Students were asked to include the source of their problems, if they used any, at the end of each problem so that the graders could do reference checking. During the grading, the Instructional Assistants (IAs) randomly selected some problems from some submissions and checked their references. In addition to submitting the problems and their solutions, students were asked to tag their problems with the learning outcomes created for the course and rate the cognitive level of their problems. The course learning outcomes were developed by the instructor and posted on the course website. At the beginning of the summer session, the instructor introduced to students three cognitive levels based on Bloom's taxonomy. These levels were level 1: remembering and understanding equations; level 2: applying and analyzing; level 3: evaluating and creating. The instructor also rated the cognitive levels of the problems in one of the past final exams and shared the file with students for reference.

With the goal of encouraging students to challenge themselves and develop problems at higher cognitive levels without the fear of losing points on their total grade, the submitted questions were graded based on completeness. Complete submissions included the references used for designing the submitted problems, ratings of the cognitive levels, the Learning Outcomes (LOs)

linked to each problem, the required number of problems, and complete answers to those problems. To ensure that students received timely feedback on their designed problems and their submitted solutions, all students were asked to attend mandatory one-on-one meetings with an IA or the instructor. During the meetings, either the students selected a problem that they struggled with and worked on that problem with the IAs, or the IAs selected one of their submitted problems and, using probing questions, discussed the submitted solution with the student. The appointment slots for the 15-minute one-on-one meetings were created in a Google calendar, and the calendar link was shared with students to sign up. The course in the summer session had two experienced IAs, one of whom was a Ph.D. student, and one of whom was an undergraduate student who participated in the one-on-one meetings. Students were also allowed to seek help and ask questions about their designed problems or their solutions during the instructor or IA office hours, before or after submitting their question sets.

In the summer session, two anonymous end-of-the-quarter surveys were used to get students' feedback on the new assessment method. The instructor administered one of the surveys through Google forms, and the other survey was the standard Course & Professor Evaluations (CAPES) administered by the University. The CAPEs responses from the spring quarter are used as the reference in the data analysis section of the paper.

Data analysis, results

Feedback survey about flipped classroom (Summer 2020):

In summer 2020, the instructor-designed student feedback survey at the end of the term asked students a variety of questions about the class format and assessments.

Students generally reported that the flipped classroom format was helpful and that they regularly engaged with asynchronous class materials. Students were asked to what extent they agreed with the statement that the structure of the class (flipped classroom) was helpful for learning course topics. They responded on a 5 points scale from "strongly disagree" (numerically 1) to "strongly agree" (numerically 5). Students tended to agree, with an average rating of 4.4 (sd = 0.6). Students were also asked how often they watched the lecture videos prior to the live class sessions. They responded on a five-point scale from "almost never" (1) to "almost always" (5). Most students reported that they did indeed watch the lectures prior to class, with an average response of 4.5 (sd = 0.7)

Feedback survey about the student-designed question sets (Summer 2020):

Students were also asked targeted questions about the student-designed question sets. The student survey included open-ended survey questions about the positive aspects and drawbacks of the student-designed question sets as well as soliciting feedback about the IA meetings. Common themes in student comments are highlighted in tables 2 and 3 below.

Table 2. Feedback survey responses about the positive aspects of the novel assessments in Summer 2020

Positive aspects of the novel assessment method	Frequency of the response
Better/Deeper Understanding of Content	35% (12/34)
More engagement with class materials	32% (11/34)
Focus on areas of confusion	12% (4/34)
Reduced Stress/Anxiety	21% (7/34)
Follow Up Meetings Helped	15% (5/34)

Table 3. Feedback survey responses about the drawbacks of the novel assessments in Summer 2020

Drawbacks of the novel assessment method	Frequency of the response
Unsure about the connection to final exam	23% (8/35)
Picked only easy questions for quizzes	23% (8/35)
Unsure whether quiz answers were correct	17% (6/35)
Too time consuming	9% (3/35)

Overall students seemed to find the meetings especially helpful. This finding aligns with the results of a previous study that found explanatory feedback on exam performance to be particularly valuable for learning [31]. Table 4 shows the common themes in student responses to a question about the follow-up meetings with IAs.

Table 4. Feedback survey responses about the one-on-one follow-up meetings in Summer 2020

One-on-one follow-up meetings	Frequency of the response
Helped to notice errors/misunderstandings	42% (11/26)
Used the term “helpful” specifically	35% (9/26)
Wanted them to be longer	12% (3/26)
Other positive adjectives	85% (22/26)

CAPES - Numeric

Students filled out Course & Professor Evaluations (CAPES) at the end of each quarter. These surveys include a series of questions where students respond to a statement on a scale from “Strongly Disagree” (numerically 1) to “Strongly Agree” (numerically 5). There were some significant differences between spring and summer on a couple of these questions.

When asked to what extent they agree with the statement, “I learned a great deal from this course”, students in spring 2020 reported agreeing with an average of 4.25 (sd = .83), and students in summer 2020 agreed with an average of 4.5 (sd = .66). A Welch t test revealed that these responses were significantly different, t(92.2), = -1.99, p = .048. Students more strongly agreed with this statement in summer 2020 than they did in spring.

When asked to what extent they agree with the statement, “Exams are representative of course material”, students in spring 2020 reported agreeing with an average of 4.44 (sd = .68), and students in summer 2020 agreed with an average of 3.85 (sd = .86). A Welch t test revealed that these responses were significantly different, t(44.6), = 3.72, p < .001. Students agreed less with this statement in summer 2020 than they did in spring.

CAPES - Free response

Student free responses on the CAPES when asked about “Exams/Quizzes/Papers” echoed common responses on the student surveys. Students reported that the self-designed quizzes helped them focus on areas of confusion, with comments like: “let me target material I was weak on.” Students reported the follow-up meetings with IAs were helpful, with comments like: “really liked… to have a short meeting with the IA to talk about what you want to know.” Students also reported generally liking the quiz format, with comments like: “The self designed quizzes was an interesting concept and I think there is great potential in the idea,” and “Amazing format of self-designed quizzes weekly.”

The drawbacks students reported on the CAPES were also similar to those identified in the instructor-designed survey. Students reported being unsure of how the quizzes would connect to the final exam: “wished there was a better way to prepare for the final exam-like difficulty questions.” They also reported being able to design ‘easy’ problems for the quizzes that didn’t help to deepen understanding, with comments like: “it would be easy for me to just take an old exam question and just change the numbers but i wouldn’t feel like I was learning a lot that way,” and “very tempting to come up with very boring problems.”

Correlation between student-selected cognitive levels on quizzes & final exam grades:

Students were asked to rate the cognitive level of each problem they designed for their quizzes from 1-3. The mean rating was 2.24 with a standard deviation of 0.48. Many student ratings were missing or illegible. Students who clearly rated at least half of their quiz problems throughout the class (26 of the 57 students enrolled) were included in a correlation analysis. There was no significant correlation between a given student’s average rating on their quiz problems and their grade on the final exam, $r(26) = .0076$, $p > .05$.

Inter-rater reliability of student cognitive level rankings:

The instructor selected six students at random and independently rated the cognitive level of each of their quiz problems. These ratings were compared to the student ratings. There was a 63% agreement between student and instructor ratings. In cases of disagreement, the instructor gave a higher rating than the student 40% of the time, and the students gave a higher rating 40% of the time. Inter-rater reliability was also calculated using Cohen's Kappa, which indicated generally a low agreement between student and instructor ratings of cognitive level (k = .051).

Discussion

In traditional exams, the learning usually ends when students take the test. In our experience, only very few students refer back to their graded work to enhance their learning further. In this new assessment method, the learning is a continuous process that starts before the exam, continues while students work on the problems, and extends to after they submit the solutions. To design the questions, students reviewed the course materials, examined the lecture note and textbook problems, developed new questions related to the learning outcomes, and reflected on the cognitive level of their selected problems. After solving the problems and submitting their work, they attended follow-up meetings to get feedback on their work and clarify any confusing concepts. In the end-of-quarter survey in the summer course, several students mentioned that they found the new method helpful to their learning. Comparing the percentage of students who agreed with the statement "I learned a great deal from the course" in the Course & Professor Evaluations (CAPES) in spring and summer 2020, we noticed that there is a statistical difference between the averages in two sessions. The average for this statement was higher in the summer 2020 CAPE report. This finding is in agreement with the research results reported in the literature indicating that self-assessment, reflection on learning, and receiving feedback on learning support student learning [7], [8].

In the end-of-quarter feedback survey in summer 2020, some students pointed out that because there were no restrictions on the cognitive level of the selected problems and there were no penalties for choosing simple problems, some students chose easier problems and did not challenge themselves. Student concerns about question quality have also surfaced in previous research on student-generated exam questions, even if students also reported finding the student-designed exams beneficial to their learning in general [10], [17], [18]. In addition, in our study, comparing the CAPE results in spring and summer sessions, we noticed that the average percentage of students who agreed that "the exams were representative of the course materials" in summer was less than the one in spring. We believe there must be some restrictions on the type of problems that students select. The summer session was the first time that such assessments were integrated into the course, so the instructor proposed minimum restrictions on the selection of the assessment problems. In the paper's future work section, we will discuss our plans to respond to this feedback and observation.

The follow-up meeting component of these assessments was well received by the students. The meetings increased the interactions between students and the instructional team members and provided students with an opportunity to receive timely feedback on the concepts they were confused about. These findings are in agreement with the results reported in the literature about the benefits of student-faculty interaction and explanatory feedback [29], [30], [31], and it is also notable that previous research has found that increased levels of student activity in discussing and interacting with peers about student-generated questions in the PeerWise system seemed to be linked to additional learning gains [9], [10], or to account for at least part of student learning gains seen from this approach [32]. In other words, this study's findings offer further support for previous findings, suggesting that the opportunity to discuss problems with peers or instructional staff appears to be an important way to reinforce and deepen student learning surrounding self-designed exam problems.

There were some disagreements between how the students rated their problems' cognitive levels and how the instructor rated those problems. At the beginning of the quarter, students were introduced to the definition and explanation of three cognitive levels selected from Bloom's taxonomy. In addition, the instructor rated the cognitive levels of the problems on a sample past final exam and shared it with students to use as an example. The authors believe that providing written or oral feedback to students on their ratings of cognitive levels could result in a better correlation between their ratings and the instructor's ratings.

The authors believe that the new assessment method contributes to improving the integrity of the tests, particularly in online classes, as every student submits a unique set of questions and answers. In the course under study, students were required to modify the problems if they used textbook or lecture problems. They were also required to provide the source of their problems if an already published problem inspired them. The IAs (Instructional Assistants) checked their references while grading their work for completeness and discussed the reference problem modifications in the follow-up meetings.

Future work

In the future, the course instructor will provide a more structured framework for the assessments. There will be some limitations on the design of the problems that will be given to the students. In addition, we will explore the integration of a peer-review component to the assessments, so students could examine the problems proposed by their peers and review the solutions. Furthermore, we will form focus groups and interview students to use them as a supplementary data collection tool.

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