Full Paper: One Tool to Support Attendance, Engagement, Metacognition, and Exam Preparation

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Introduction: Course Structure and Motivation

Case Western Reserve University's first-year engineering experience is a one-semester course required for all engineering majors that may be taken in either the fall or spring semester. The course exposes students to a breadth of engineering disciplines while developing their skills in programming, teamwork, and design. There are two 75-minute lab meetings per week and one common 75-minute lecture a week. The lecture serves two primary purposes: to instruct students in MATLAB coding and to introduce them to each engineering discipline on campus. The MATLAB portion of the lecture, about 55 minutes, is delivered by the course instructors; typically, this is led by one instructor with the others assisting during active learning exercises. The remaining 20 minutes consist of a guest presentation by a faculty member from one of CWRU's engineering majors. The guest lectures typically combine an overview of the discipline including typical problems solved, some stories of current work going on at the university, a description of the major requirements and student activities, and sometimes a bit about the presenter's own career path. While the students explore about half of CWRU's available engineering programs in more depth during the laboratory activities, their initial exposure to the other half is strictly through these presentations.

The course was piloted in 2019 with around a dozen students and one instructor and steadily expanded. In the 2022-23 academic year, it became an engineering requirement with up to 230 students in one semester, taught by a team of two full-time faculty, one adjunct instructor, and twenty undergraduate assistants. As it grew, the lecture's atmosphere naturally changed. It was less conversational, less personal, and more formal. These observations are in line with existing literature that found links between increased class size and reduced student involvement, reduced depth of student thinking in class, and reduced frequency and quality of feedback to students [1]. The instructors, who met weekly to discuss potential course improvements, identified manifestations of these issues in several specific areas:

1) Metacognition and formative feedback – formative feedback is key for students to develop the metacognitive skills needed for self-regulated learning [2] [3]. In the early years of the course, instructors could easily have conversations with individual students to help them reflect on their learning approach, provide feedback, and suggest new strategies. After a few years of expansion, these conversations tended to only happen with students during office hours. The first lecture of the course has always contained a section on metacognition, and as the course has evolved, the instructors have posted resources inspired by the metacognition literature [4] [5]. Students were encouraged to self-quiz themselves regularly and not cram for exams. They were also given an assignment to reflect on and correct mistakes on their midterm exam [6]. However, it was unclear how many students embraced these ideas. To help make metacognitive learning strategies a habit for students, the instructors sought to weave more metacognitive opportunities into the lecture.

2) Attendance – when the total course enrollment was 30 students or less taking the course voluntarily, absences were rare. In the spring of 2022, when the enrollment was

approximately 120 students and recorded lectures were still being posted for quarantined students, sometimes only about one-third of the class was present in the classroom. Questions asked by a noticeable portion of the absent students when trying to complete the associated homework often indicated they had not effectively processed the posted material. Additionally, as the guest lectures are the primary mechanism for introducing the engineering disciplines, poor attendance meant that this course goal was not being met. In the fall of 2022, the instructors added a weekly quiz administered through the course management system based on each guest presentation. The goal was to ask a few very basic questions that were clearly answered during the presentation. However, some presentations did not lend themselves well to this style of assessment. Further, this shifted the student focus to identifying potential topics for quiz questions, instead of getting an overview of a potential area of study.

3) Interaction with guest presenters – as the enrollment increased, students asked fewer questions. Even if a guest left a few minutes for questions, given the broad nature of the presentation and the variations in student background and interest, there was never enough time to take all questions. While every week a few students would remain and talk with the presenter afterwards, not all students could participate in this opportunity.

4) Administration and format of exams – when there was only one lab section, exams could be administered in any class period and consisted of several coding problems that students would solve on their laptops and submit through the course management system. With multiple sections, a common exam had to be administered in a large space with very few electrical outlets. Since students could not be expected to take a three-hour, computer-based, final exam on battery power alone, it became clear that at least some portion of exams would need to move to a paper-based administration. This change in exam format would lead to different styles of questions, and the instructors began considering options for how to familiarize students with these question types prior to the test.

The instructional team made multiple modifications to enhance student learning in the larger class. Zakrajek recommends instructors address growing class sizes by, among other things, seeking methods to incorporate prompt feedback and active learning opportunities [7]. This paper focuses on one such strategy designed to address the four concerns identified above: the weekly formative lecture quiz. The online quiz based on the guest lectures was eliminated.

Weekly Formative Lecture Quizzes

Process

Each week, as students walk into the lecture hall, they pick up a half sheet of paper. The front side of it consists of a few short questions based on material from the previous week's lecture. To emphasize that it is not a summative exercise, it is always titled "LOW STAKES FORMATIVE LECTURE QUIZ" with these directions: "Answer the following questions without consulting any resources. The point of this activity is for you to test your knowledge. Full credit will be given for a good effort in answering the questions." Students work on the quiz as they wait for the lecture to start. A few minutes into the class period, the instructor begins by going over the quiz, encouraging students to ask questions and to make any notes for themselves

about concepts they might want to review later. Sometimes the instructor also poses a few quick extension questions. Often, the quiz can serve as a segue between the previous and new material. There is space on the quiz for students to write their name and circle their lab section.

Students keep the quizzes through the lecture. The back side of the paper contains the prompt, "Write down any questions you have for today's guest lecturer. We will compile and post them, along with responses, in the Canvas Resources module." The students write questions throughout the guest presentation. Sometimes the presenter allows time for questions, but more often they do not. Regardless, they encourage students to chat with them after class if they would like.

Students turn in the quizzes as they leave class, in piles separated by lab section. The quizzes are "graded" by an undergraduate teaching assistant within a couple of days of the lecture. As the directions indicate, students receive full credit for an honest attempt at the MATLAB questions. There is no requirement that they write a question for the guest. The formative quizzes are 3% of the final course grade. The TA also compiles the questions and tallies them to see which are the most common. When the TA is finished, the quiz papers are returned to the course instructors. The compilation of questions is sent to one of the instructors, who sends several of the most common ones to the guest to answer. Most of the guests respond within a few hours to a week. The instructor then posts a document with the questions and answers to the course management site. Usually there are questions that are repeated from one semester to the next, so large portions of the previous term's document can be reused.

Quiz Design

The questions are short and address the most fundamental principles introduced in the previous week's lecture. They also are written in a variety of styles to reflect most of the kinds of questions students might expect to see on their exams. The current set of lecture quizzes includes questions where students are asked to:
- select the correct multiple-choice response
- complete partial code by filling in blanks
- determine the output of a code snippet
- write a single line of code to complete a task
- write a few lines of code or a short function to complete a task
- put scrambled code in order
- identify and describe how to fix bugs in a short segment of code
- find mistakes and assumptions in algorithms

Effectiveness of Activity in Meeting Goals

The modest analysis that follows is based on student grades, a question on a semester-end survey, and instructor observations. While it is not possible to isolate the effect of the formative lecture quizzes on student engagement and learning from several other improvements that were made to the evolving course, there are many indications that this activity was effective in meeting the goals for which it was designed. There are also opportunities for improvement and opportunities to collect more data.

Metacognitive Modeling

The common directions on each quiz remind the students of the metacognitive purpose of the exercise. Of course, just because the words appear on the paper does not guarantee that the students will read them. While it seems that often students will talk about the quiz with their friends while they are writing their answers, rather than using it as a true individual self-quiz, very few laptops are open during this time, so most students are not using MATLAB or posted course materials to answer the questions.

When the instructors present the quiz answers, it provides a weekly opportunity to discuss metacognitive strategies. This can be modest and quick, such as saying, "If you had trouble with this question, make a note for yourself to review this part of last week's lecture." Sometimes it might be more involved, such as instructing the students, "Take a minute and look over the correct answer. What do you think are a couple of the most common mistakes people made? What is the mistake that you would be most likely to make if you saw a question like this again? Talk about it with the people around you."

A question on the spring 2024 semester-end survey asked students to rate twelve course elements on a 4-point scale from "not at all effective" (1) to "highly effective" (4) in aiding their learning. The majority of the class found the quiz effective, giving it a mean ranking of 2.66. However, it is notable that only the exam corrections assignment (the other major metacognitive activity) was rated lower than this. It is the perception of the instructors that the fall semester cohorts tend to engage more with these aspects of the course, and they plan to repeat this survey for several semesters to determine if there is a difference between the semesters. Regardless, there is room for improvement in how metacognition is encouraged in the course.

Attendance

Attendance is dramatically improved. It should be noted, however, that there have been other modifications to the lectures that would be expected to contribute to this finding, including that recordings of them are no longer posted. There are no formal lecture attendance records from before the quizzes were implemented, but as mentioned before, there were many days when it was easy to notice that the attendance was 60% or less. During both semesters of the 2023-24 academic year, the average lecture attendance, as measured by submitted quizzes, was 93%. Only one class period had less than 90% of the students in attendance, and that was the week of Thanksgiving.

Engagement with Guest Lecturers and Topics

Students are not required to submit questions for the guest lecturer, but on average, about half do. In a typical week, questions will touch on all the facets of the presentation, including questions about examples shared in the lecture, the program at the university, extracurricular activities in the major, and career opportunities. There are typically some questions asking the presenter about favorite projects or experiences, as well. The first semester that this approach

was implemented, almost every presenter commented on the excellence of the questions, and several specifically stated that they enjoyed answering them. Sometimes students also share compliments for the presenter in this space, which are passed along. While not every question is able to be answered, many more are than were before the quizzes were implemented; this has expanded the opportunity for students to learn about the engineering disciplines and given the departmental faculty insight into the first-year student's thoughts.

An additional benefit is that on the occasions when the guest presenter solicits questions, there are always several students who have questions ready, presumably because they have already written them down. Further, before the introduction of the quizzes, most in-class questions came from the same few students; now there are more students who participate.

Exam Preparation

Because the quizzes are collected at the end of the lecture and because the solution to the quiz is discussed during class, there is no way to know how much of a student's answer was written before or after the discussion. Indeed, looking through the responses reveal that most papers have correct answers. Occasionally, there is some evidence that a student changed part of their answer, but that correction could have happened while they were originally answering the question, or it might have occurred during the class discussion. Therefore, the current analysis of how the quizzes might help with exam preparation focused on the alignment between question formats on the formative quizzes and the exams.

The styles of questions on the formative quizzes corresponded well with the questions on the midterm and final exams, as shown in Table 1. Question styles are ordered roughly by Bloom's level, from low to high. The numbers in the Quizzes column indicate the week(s) each style of question appeared. An 'x' indicates that that style appeared at least once on the exam.

Table 1. Summary of Occurrences of Question Styles on Assessments

Question Style	Quizzes*	FA 23 Midterm	SP 24 Midterm	FA 23 Final	SP 24 Final
Multiple Choice	14			x	x
Fill-in-the-Blanks	3,13	x	x		
Matching				x	x
Determine Output	4,10, 11	x	x	x	x
Write One Line	6, 9, 11	x	x	x	x
Write a Snippet	4, 5, 9, 12	x	x	x	x
Unscramble Code	5				
Debug Code	8, 14			x	x
Algorithm Evaluation	2		x	x	x

*There is no quiz 7, as that was the week of the midterm exam.
A short survey was given in week 1 instead of a quiz.

There are only two types of questions that do not appear on both the formative quizzes and on an exam. The final exam both semesters had a question where students had to match graphs to the

lines of code that generated them in a code segment. While answering this question requires students to use largely the same skills as a "determine the output" kind of question, the format is different. However, it should be noted that the students were not confused by the new format, as 99% of them got the matching question completely correct. The other style of question, which appeared on Quiz 5, gave students eight lines of code in a scrambled order and asked them to reorder them to accomplish a particular task. The instructors liked this "Parson's problem" [8] format and the discussions it generated but felt that it would be challenging to grade on an exam, so opted to use it as a learning tool only. It should also be noted that most of the exams contained one or two questions that asked students to write longer segments of code than on the quizzes, and those are not included in this analysis.

Conclusions and Future Work

Weekly formative quizzes were added to the activities in the lecture section of a first-year engineering course. The quiz experience was designed to do four things: model metacognitive learning strategies, improve lecture attendance, provide a vehicle for more students to ask the guest lecturers questions, and prepare students for the question styles on paper-based exams.

Analysis and observations during the 2023-24 academic year indicate that the quizzes were reasonably successful in meeting these goals. Instructors modeled metacognitive strategies for the students on a more regular basis, but student feedback indicates some additional scaffolding may be necessary for students to more widely embrace these strategies. Attendance increased to an average of 93% of students at each lecture. Guest lecturers have answered more questions from a more representative sample of the class than they did before. Students have familiarity with the styles of questions that are asked on paper-based programming exams.

One opportunity for improvement is to make the alignment between the question styles on the quizzes and the exams stronger by incorporating a matching question somewhere in the quizzes. Another potential improvement is to encourage students to make it more obvious to themselves (and the instructors) on the quiz paper what they knew when they initially completed the quiz and what they corrected after the class discussion. One way that this might be done is by asking them to initially answer the quiz in pen and then make notes to themselves in pencil afterward. In light of the survey data, instructors will likely add a common set of scaffolding questions to the wrap-up discussion of each quiz.

The instructional staff is pleased with the addition of the formative lecture quizzes and plans to continue their use for the foreseeable future with minor modifications as outlined above. They will collect additional student feedback to assess the impact of these modifications.

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