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Benefits of Active Learning Embedded in Online Content Material Supporting a Flipped Classroom

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Abstract:

In the traditional flipped classroom paradigm, the course content is delivered online in advance of classroom time, which is reserved for active learning applications. The paradigm does not prescribe the inclusion of active learning in the online content. We examined the impact of embedding quizzes in the online content which required students to immediately apply the lessons' content for problem-solving.

Our Medical Electronics course has been structured as a flipped classroom since 2014. In the 2017 offering, video quizzes were embedded in the fourteen online lessons that support the course. Each lesson video quiz comprised 3-5 short problems, formatted as free-response and objective questions. The students were told that simply attempting the quizzes would count for a small percentage of their overall course score. The software used to produce the online video lessons generated worksheets listing the students' responses to the embedded quiz questions scored for correctness.

We examined the participation rate of the students in answering the online quiz questions during the semester and their quiz scores. We also investigated the correlations between participation and score on the online quizzes with performance on summative measures of assessment. Last, we compared the rate of online lesson viewing for the student cohort who had access to the video quizzes with the lesson viewing rates of prior cohorts who used the online lessons without embedded quizzes.

We found that about 80% of students answered the online quiz questions. Receiving a high score on these questions was positively correlated with good performance on the summative assessment measures ($p < 0.01$). The inclusion of on-line video quizzes coincided with an increased viewership of the online video lessons that was sustained during the semester in comparison to the lesson viewership observed in prior offerings of the course.

We conclude that the inclusion of online quiz questions in the video lessons added an active learning component to the lessons which increased the students' motivation to study the online content. Active learning exercises improves learning of the online lessons in the flipped classroom.

Introduction and background

The flipped classroom approach has increased in popularity for engineering and science courses [1] [2] in part because the traditional lecture approach is perceived to be ineffective for teaching essential problem-solving skills [3]. Time spent in the classroom is thought to be better used when the instructor supports students working in groups on problem-solving and other active learning activities. While many variants of the flipped classroom approach have been described, the essential pedagogical aspects include 1) offloading the transmission of information out of the classroom for consumption before class time; 2) use of class time for active group learning; 3) pre- and post- class activities for students to further practice with the skills practiced in the classroom [3].

In most flipped classroom implementations, the course content is presented through video lessons accessed online and which are either prepared by the course instructors or curated from existing sources [2]. The flipped classroom approach does not prescribe to include in the online content means for the students to test their knowledge and understanding. In some reports, flipped classroom videos included formative tests [2][4]. In other studies, the online content solely presented essential knowledge, concepts, and methods of analysis, while understanding was tested at the beginning of the in-class meetings through question-and-answer sessions or with short quizzes [2] [5] [6]. Previous studies [7] reported that pre-class quizzes on the lecture material benefited students' preparation without specifying the format to use for the quizzes (online vs. in-class, graded for participation or correctness). Other studies could not attribute a clear benefit to preparatory online quizzes [4].

The purpose of this study was to determine if including formative quizzes in the video lessons of a flipped classroom altered the students' propensity to watch the video lessons and to prepare for the in-class activities. We examined if students participated in the online formative video quizzes and if such participation correlated with success on summative measures of performance. The starting point of the study was a course that had been taught as a flipped classroom for several years [6] such that we could attempt to isolate the effects of the online formative quizzes on student involvement and learning.

Methods

Context

The "Medical Electronics" course at our institution is a 4-unit required course in the curriculum of our Biomedical Engineering undergraduate program with an enrollment of 45 – 50 juniors and seniors. The course offered every Spring during a 15-week semester presents the analysis and design of analog electronic functions commonly found in measurement systems and medical instruments as well as the components used to implement these functions in hardware. Students learn about sensing with medical transducers, signal amplification and signal conditioning with transistors, operational amplifiers, instrumentation amplifiers, bridge amplifiers, and active filters, as well as DC power generation and linear DC power supplies built with transformers, diode bridges, capacitors, Zener diodes, and voltage regulators.

The students attend two 80 min classroom sessions and one laboratory session each week. In the laboratory, the students practice to design and implement the functions studied in the classroom [8]. To accommodate the large enrollment, two or three laboratory sessions are offered each week with comparable numbers of students in each session.

The lecture part of the course has been taught with the flipped classroom instructional approach since 2014 to promote active learning by collaborative problem-solving [9] [6]. Students are assigned video lessons to watch every week that present the essential knowledge content and a few sample problems with solutions. The narrated videos (15 - 20 min duration) were developed with Camtasia (versions 8 and 9, Techsmith) from Powerpoint slides, which are also available to the students on the Blackboard Learning Management System (LMS) for reviews and reminders.

In the classroom, for each new topic, a short discussion takes place prompted by the questions the students raise about the video lesson. The discussion is followed by a group quiz with conceptual and problem-solving questions that is used to further activate the students' knowledge and retrieval of the lesson's content. The answers to the group quiz are reviewed with the class, each group marking the answer sheet of a different group. The group or groups with the highest scores in the group quiz receive 1 bonus point to be applied toward the individual quiz the students take at the end of each lesson or group of lessons (equivalent to 25% of the maximum individual quiz score). The group quizzes confer a game-like atmosphere to the initial discussion of a new topic. They were adopted at the same time as the flipped classroom approach to motivate the students to watch the video lessons when each new topic is introduced.

Thereafter, the students work in groups of 4 to 6 to solve problems from an assignment sheet, with the instructor and one teaching assistant roaming the room to observe how the students are addressing the problems, provide personalized hints or clarifications, identify conceptual errors, and guide the students through each exercise. Depending on the ease with which the students handle each exercise, the class agrees on the answers to the problem and proceeds to the following problem or the solution is discussed at the board with the instructor prompting the students' groups for clarifications about their approach for solving the problem.

We assess students in the course with quizzes taken individually and administered approximately every 10 days, one midterm exam, and one final exam. All the assessments are in the form of problem-solving objective questions, 4-5 questions for the quizzes, 20-25 questions for the midterm exam, and 30-35 questions for the 2-hour final exam.

Intervention

The LMS records automatically if the students access the video lessons in their entirety, in part, or not at all. In this way, we can track the percentage of students who access and complete the video lessons during the semester. We had observed in the previous offerings of the course that the percentage of lessons viewed by the students decreased as the semester progressed [10]. Therefore, an incentive to watch the video lessons was built into the recordings in the form of problem-solving quiz questions (3 or 4 for each lesson). The students were told that if they attempted to respond to the quiz questions, they would receive a small participation bonus applied toward their overall course score, irrespective of the correctness of their answers [11].

The quiz feature of Camtasia was used to embed the questions in the video lessons. Free-response and objective problem-solving questions were used, that asked the students to compute a quantity (voltage, current, gain) in a circuit presented in the background of the video image. The quiz questions addressed important methods for circuit analysis that had been presented in the video lessons in the form of detailed solved examples and problems for the students to solve on their own (only final answers provided). Thus, the quiz questions mainly examined if the students could on their own analyze circuits similar to those presented in the video lessons or expand on the lesson content to analyze a new circuit with the same methods of analysis. After each question was answered, the students received feedback indicating if they had entered the correct answer, or in the case of an incorrect answer, the correct answer, and a hint to address the question correctly.

Attempting to answer the quiz questions was voluntary, such that the students could choose to view the video lessons without attempting the quizzes. Students who chose to answer the quiz questions were prompted to enter their name and email address. There was no restriction on how many times the quiz questions could be answered, but the students had to restart the video lesson from the beginning and re-enter their contact information to retake a quiz.

The quiz software automatically tabulates when students attempt to solve the quiz questions and generates an email message with attached Excel worksheets listing the students' scores and the times at which the video was started and ended for each attempt at answering the questions.

The worksheets generated 7 to 10 days after each video lesson was assigned were retrieved and examined to identify the students who had attempted the quiz and extract their score. When students took the quiz several times, the highest score was retained. The student scores were converted into a percentage to account for the number of questions in each video quiz.

Data analysis

Quizzes were embedded in 14 of the 16 video lessons used to present the course content. For each student, we tabulated the score in each video quiz and computed the average video quiz score for the semester. Participation (1 = Y, 0 = N) was also counted for each video quiz and averaged to determine the average participation percentage for each student.

The student scores in summative assessment measures: average of 7 in-class quizzes, midterm exam, final exam, and overall course score (a weighted average of all exams and quizzes, homework marks, and laboratory marks) were determined. Pearson r correlation coefficients were computed to assess the relationships between participation and average score in the video quizzes with the student scores in the summative assessment measures.

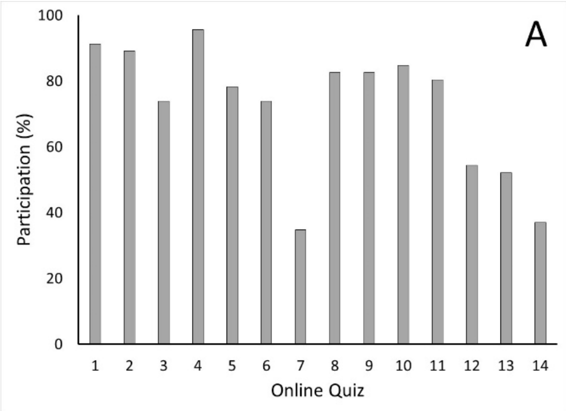
In addition, access to the video lessons was compared for the course offering in which the video quizzes were used and access in the two previous semester offerings for which the same videos were used but without embedded quizzes. The semester was divided into four consecutive periods of 4 weeks to determine if embedding the video quizzes altered the frequency with which the students accessed the video lessons as the semester progressed. The LMS records automatically when students access the video lessons. Access to each lesson was scored for each student as 100% (lesson completed), 50% (lesson partially completed), or 0% (lesson not accessed). The average viewing score for all the students enrolled in the course was determined over each 4-week period. A general linear model analysis with two factors (video quizzes: Y-N, 4-week period in semester: 1-4) was used for this analysis.

Furthermore, the final exams of the course offering in which the online video quizzes were used and of the preceding course offering comprised 23 identical questions. The average scores on these 23 questions were compared using a paired t-test. All statistical tests were performed with SPSS.

Results

Forty-six students enrolled in the “Medical Electronics” course for the semester in which the quizzes were used in the online lessons, which was near identical to the enrollment for the two previous offerings of the course (45 and 46).

The percentage of students who participated in the online quizzes hovered around 80% for the 14 quizzes spread out over the semester, except for drops just before the Spring semester recess and toward the end of the semester (Fig. 1A) indicating the students were engaged and motivated to attempt answering the quiz questions. The average score in all the online quizzes was 54% and varied without trend during the semester (Fig. 1B), suggesting that the quizzes were sufficiently challenging and that watching the online lessons alone was not sufficient for the students to answer all the quiz questions satisfactorily.



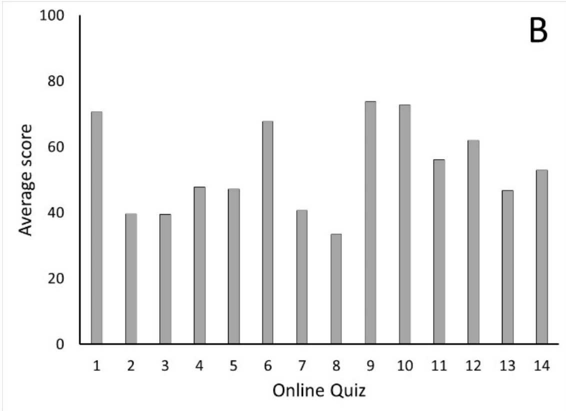


Figure 1: average participation (left, A) and average score (right, B) for the 14 online quizzes

The rate of participation in the online quizzes for each student was significantly and positively correlated with the student score in the in-class quizzes, the midterm exam score, and the overall course score (Table 1). Likewise, the students' score in the online quizzes was strongly correlated with their performance on all summative measures of course achievement (Table 1).

Online quizzes	**Score class quiz**	**Score midterm**	**Score final exam**	**Course score**
% participation	0.315 (0.033)	0.310 (0.036)	0.269 (0.071)	0.346 (0.018)
Average score	0.399 (0.006)	0.482 (0.001)	0.437 (0.002)	0.509 (0.001)

Table 1: Pearson correlation coefficient and significance presented as: r (p-value) for relations between the students' involvement in the online quizzes (% participation and average online quiz score) and the summative measures of assessment (average in-class quiz score, midterm score, final score, overall course score).

On average, there was a 9.7% improvement (80.4% vs. 70.7% average score on 23 questions, $p < 0.001$) on the final exam results for the course offering that used the online video quizzes over the preceding course offering.

Addition of the video quizzes in the online lessons positively altered the viewing patterns of the flipped classroom lessons (Fig. 2). In preceding years, lesson viewership decreased from around 80% in the first 4-week period of the semester down to 50% in the last 4-week period. In contrast, viewership remained > 65-70% for most of the semester when the video quizzes were added to the online lessons. Overall semester viewership increased significantly from 62% to 72% when the video quizzes were embedded in the video lessons.

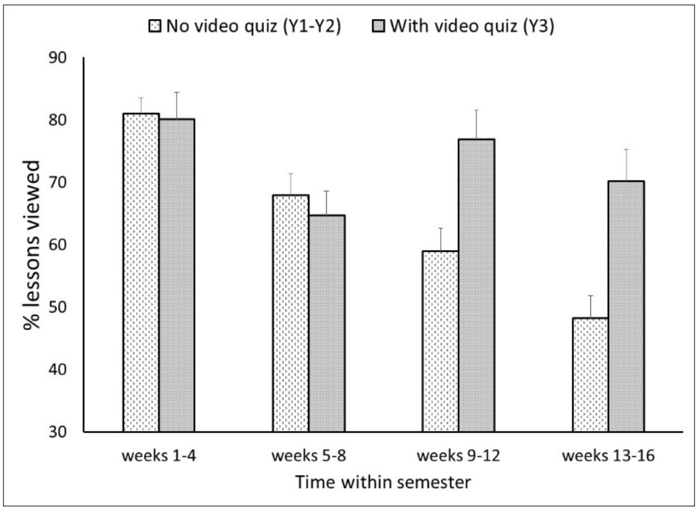


Figure 2: average % lessons viewed as a function of time by all students in the course during the semester (mean ± SD). Significant effects of time in the semester ($p<0.001$), presence of the online quizzes ($p<0.001$), and interaction between time and presence of the quizzes ($p<0.001$) are observed. The mid-semester drop likely reflect the fact that multiple midterm exams scheduled in weeks 5-8 decreased the time available to the students for viewing the online lessons.

Discussion

In this one-year study, we found that students readily participated in formative quizzes included in the online video lessons supporting a flipped classroom. Participation was sustained during the semester-long course. Students who participated more frequently in the online quizzes and who scored well in these formative assessments tended to also score highly in the summative assessment measures (in-class quizzes and exams). Inclusion of the online quizzes positively affected how much the students watched the online lessons, particularly toward the end of the semester when focus switches away from coursework, particularly for the senior students who comprise ~50% of the course enrollment.

Participation in the online quizzes was voluntary and students were told that a small, yet undefined percent bonus applied toward their final course score would be associated with their participation. Thus, it seems unlikely that students would attempt answering the quiz questions solely to receive this bonus. Rather, the online quizzes added an active learning component to watching video lessons. The students were probably curious to know if they could answer the quiz questions correctly. They attempted to solve the quiz problems which were sufficiently but not too challenging such that the students consistently answered about half of the questions correctly. Overall, it appears the addition of formative online quizzes to the flipped classroom video lessons increased the motivation of the students to watch the videos and in this way, prepare for the in-class activities.

In their analysis of the flipped classroom, Abeysekera and Dawson [3] postulated that flipped classroom approaches could increase the motivation of students to learn and engage with the course material. They distinguished between extrinsic motivation (expectation of a reward or punishment) and intrinsic motivation (learning activity inherently satisfying). In as much as the students expected little improvement of their course grade from participating in the online quizzes (minimal reward or punishment), it appears the online quizzes positively affected the intrinsic motivation of the students to watch the video lessons. A certain level of extrinsic motivation associated with the expectation of a bonus on their overall course score could also have led the students to watch the online lessons and participate in the video quizzes.

McLaughlin and colleagues [5] compared student performance and attitude in flipped classroom study of first-year pharmacy students. They found a small but significant improvement on the final exam scores for the flipped classroom students when compared to students taught with the traditional lecture format. A similar observation was previously reported for the current course [6]. Student attitude assessed through a survey revealed that the students felt more confident with their learning and understanding of the course content in the flipped classroom. The authors explained the observed improvements by an increase of the students' intrinsic motivation. Intrinsic motivation is comprised of three components: ability to learn at one's own pace (autonomy), group work during the in-class activities (relatedness), and ability to identify one's learning gains through frequent assessment and feedback (competence). Addition of the online quizzes in the video lessons of our course contributed the students' ability to assess their individual understanding of the course material before coming to class and in this way, gain a sense of their competence.

The final exam performance of students improved by about 10% for the year in which the online video quizzes were used over the preceding year. While this result is encouraging, we note that the presentation of the course content had been reorganized to change the emphasis on certain topics (integrated devices) and present them earlier than other topics (transistors) such that other factors could have benefited the student performance in addition to the online video quizzes.

The online quiz questions tested the students on circuit analysis methods presented in the exposition of the lessons that are revisited in multiple examples in class when the students work in groups on problem-solving exercises and on which the students are eventually assessed through quizzes and exams. We did not specifically review the students' responses on the online quiz questions to examine if there were misconceptions to clarify in the classroom for the student cohort who had access to the online quiz questions. However, the solved examples in the video lessons and many online quiz questions were designed based on prior experience with the important problems that troubled students in prior offerings of the course.

We noted a decrease in student viewing of the video lessons and resulting smaller participation in the online quizzes around the mid-semester which we attributed to concurrent midterm exams. Viewing and quiz participation also decreased toward the end of the semester albeit not as much. Final exams at our institution take place after several "study days" after classes end, such students are less pressed for time and continue to learn the course content in the last few weeks of the semester through the online lessons and video quizzes.

The present study is limited by the fact that a single one-year cohort of students was tested with the online video quizzes in the context of a single course. We are currently repeating the approach with a new student cohort in the same course to examine if the same observations can be replicated. We will survey the new cohort to assess their perceptions of the online quizzes with respect to engagement with the video lessons, extrinsic or intrinsic motivation, and level of confidence with their understanding of the new content.

To keep the formative value of the online quizzes, we allowed the students to take the quizzes multiple times and scored the quizzes only on participation. By examining the time spent by the students to watch the video lessons, it was clear that a small fraction skipped immediately to the quizzes with little time spent on the lesson content and answered the quiz questions quasi randomly just to receive the participation bonus. Such occurrences slightly biased the participation and score figures presented in the study. In addition, the low average scores on the online quizzes (Fig. 1) may have resulted in part from the fact that the students knew that simple participation would benefit their course grade. We continue to allow the students to take the quizzes multiple times in the current offering of the course, but the online quiz scores count for a small percentage (4%) of the overall course score. We anticipate the students will take the online quizzes multiple times until they achieve a perfect score. Attempting to preempt these occurrences would deviate from the primary formative focus of the video lessons and online quizzes.

Practically, free-response questions in the online quizzes were difficult to implement because the grading software rejected answers that were correct but did not use the same number of significant digits as the programmed answers or answers expressed in a different unit (e.g. mA vs. A for current intensity). For the current offering of the course, all the quiz questions have been reformatted into objective questions.

In conclusion and in agreement with previously reported results [7], we found that including online formative quizzes in the video lessons of a flipped classroom benefited the students and was associated with increased viewership of the video learning content. Robust participation and high scores on the online quizzes was positively correlated with elevated results on all summative measures of assessment. We propose that including online quizzes in the video lessons augments the students' intrinsic motivation to learn the course content in advance of the in-class learning activities.

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