# WIP: Using Conceptual Questions to Assess Class Pre-Work and Enhance Student Engagement in Electromagnetics Learning Studio Modules

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## I. Introduction and Literature Review

Bonwell and Eisen[1] suggest that students taught in an active, student-centered environment tend to demonstrate better attitudes, improvement in thinking and writing, and retention of material. Kerr[2] also points out that the flipped classroom can encourage lifelong learning and self-regulation as well. All of these attributes are certainly useful for the students' education and their future careers.

While active learning can take many forms, this study focuses on a partially flipped classroom and problem-based learning as defined by Prince[3]. Mason et al.[4] define the flipped or inverted classroom as a pedagogical approach where students watch videos, read resources, do homework problems, or work through web-based tutorials outside the classroom. Prince[3] defines problem-based learning as an instructional method which provides relevant questions at the beginning of the class session and drive the learning which follows.

This work in progress focuses on the junior year of the Electrical Engineering (EE) program, and in particular on one of the two-course sequences constituting the EE core competencies in signals/systems, electronics, and electromagnetics. These three two-course sequences are also part of the focus of an effort funded by the National Science Foundation whose overall goal is to revolutionize engineering education[5]. A team of educators has broken each of the courses into a set of five learning studio modules (LSMs). After LSMs 1-2, 3-4, and 5, respectively, in each of the core competency areas, a knowledge integration (KI) module is conducted to illustrate how LSM concepts from signals/systems, electronics, and electromagnetics can be applied together to solve real-world engineering problems.

This paper presents and discusses innovations in teaching and learning electromagnetics LSMs aimed at increasing the student engagement, especially as related to class pre-work. Namely, with the new LSM/KI pedagogical structure and substantial portions of class time being devoted to KI sessions, it has become evident that the students must engage very intensely in the assigned pre-work that, in turn, must be carefully thought out and guided, and, most importantly, meaningfully assessed.

To this end, one of the faculty team members (B. M. Notaroš) has developed a unique and extremely comprehensive collection of as many as 888 Conceptual Questions in

electromagnetics[6], to help students comprehend anchoring concepts in this core competency, as a way of encouraging active learning through a partially flipped classroom approach and problem-based learning. These are multiple-choice questions that focus on the core concepts of the material, requiring conceptual reasoning and understanding rather than calculations. Conceptual Questions of this scope and intent are completely new in the electromagnetics area, and in practically all Electrical and Computer Engineering (ECE) areas.

In preparation for each class, students complete assigned pre-work that includes required reading and a timed, online quiz where they answer a series of carefully designed and chosen Conceptual Questions pertaining to topics in the pre-assigned reading within the current LSM. These brief, interactive assessments are both evaluating and enhancing students' understanding of the core concepts of the reading material. Such gained understanding enables students to actively engage in the subsequent LSM class taught in a flipped (inverted) classroom fashion primarily using realistic examples and problems that strongly reinforce theoretical concepts and facilitate problem-based learning. The online pre-work assessment is done for homework credit, to ensure students read the material before coming to class as recommended by Kerr[2]. The Conceptual Questions have shown to be a good assessment of students' pre-work and of how well students prepared for class, as well as a good motivator for the pre-work (reading) to be completed in the first place. They increased students' level of engagement in the classroom and their acquisition and retention of the material. Overall, the Conceptual Questions could be linked to increases in student learning.

Although the above procedure can be considered flipped, the class was actually only partially flipped[7], because the lectures only partially relied on the students' pre-work and only partially took advantage of their readiness and willingness to engage in active learning, including interactive discussion. In addition, only 14 of the total of 30 classes followed this procedure, as there were only about 14 true LSM classes, with the remaining classes being devoted to KI sessions; "creativity", "foundations", and "professionalism" sessions; midterm exams; reviews for exams; and other discussions.

## II. Methods and Implementation

The partially flipped classroom was started in the Fall of 2016 in the electromagnetics course. Prior to this, the electromagnetics offering was a traditional class and was taught by the same instructor in Fall of 2012 and Fall of 2013. In the partially flipped classroom, students were assigned readings over 14 different topics or sets of topics throughout the semester. To ensure the engagement of all students, multiple choice conceptual quizzes were given through online interactive software. The provided multiple choices contain answers that exploit potential and expected student misconceptions so that discussions of the results and correct solutions force students to address the confusion that has possibly occurred.

The web learning management system Canvas, by Instructure, was used to perform pre-work assessment, for which the students received credit. Figure 1 shows an excerpt of a sample conceptual quiz as seen by students. At the beginning of each class, the instructor poses each of the Conceptual Questions from the pre-work assessment to the class, takes a "vote" on it, and then leads a discussion on the different answers and approaches. These discussions encourage students to reflect on the reasoning behind their misconceptions and how it relates to the reasoning behind the actual solutions. Namely, the students and the instructor discuss why some (incorrect) answers appeared attractive and seemed right, and ultimately what is (or should be) the reasoning behind choosing the one correct answer. However, these interactive discussions are rather brief, taking just a very small portion of the class, to enable the other components of instruction to be carried out seamlessly. After the class is over, weekly homework assignments reaffirm the learning in class through the use of similar concepts in post-work homework. Specifically, to further solidify understanding of the core concepts, the same or similar Conceptual Questions are then given as part of the post-work homework assignment, along with computational problems based on these concepts.

## III. Preliminary Results

Because there is only one section of this course per semester (and per academic year), a controlled experiment is not an option. However, a quantitative analysis has been done based on the previous performances of the students in the 2012 and 2013 classes taught by the same instructor.

As noted in Sections I and II, this partially flipped class did not use required video lectures. Instead, the instructor used readings and graded concept quizzes to enforce engagement with the material prior to class. During classes on the flipped days (LSM sessions), the instructor would start the class by discussing the conceptual questions and the various answers given to the questions.

The impact of the new partially flipped classroom was preliminary assessed using similar final exam as in the 2012 and 2013 classes. Student scores on the final exam is a key indicator of their performance in the overall class. Table 1 summarizes the results of the final exam. As can be observed from the table, the partially flipped classroom implementation shows a higher percentage of students achieving the 65% passing mark on the final, with a much larger number of students in the class, when compared to the previous two traditional classroom instructions.

In evaluating and judging the assessment results, one should also have in mind that, although, as explained in Section I, only about 14 of the total of 30 classes were true LSM classes – to accommodate the implementation of the new LSM/KI program, the instructor was able to cover much more material due to the partially flipped classroom than in the traditional classroom

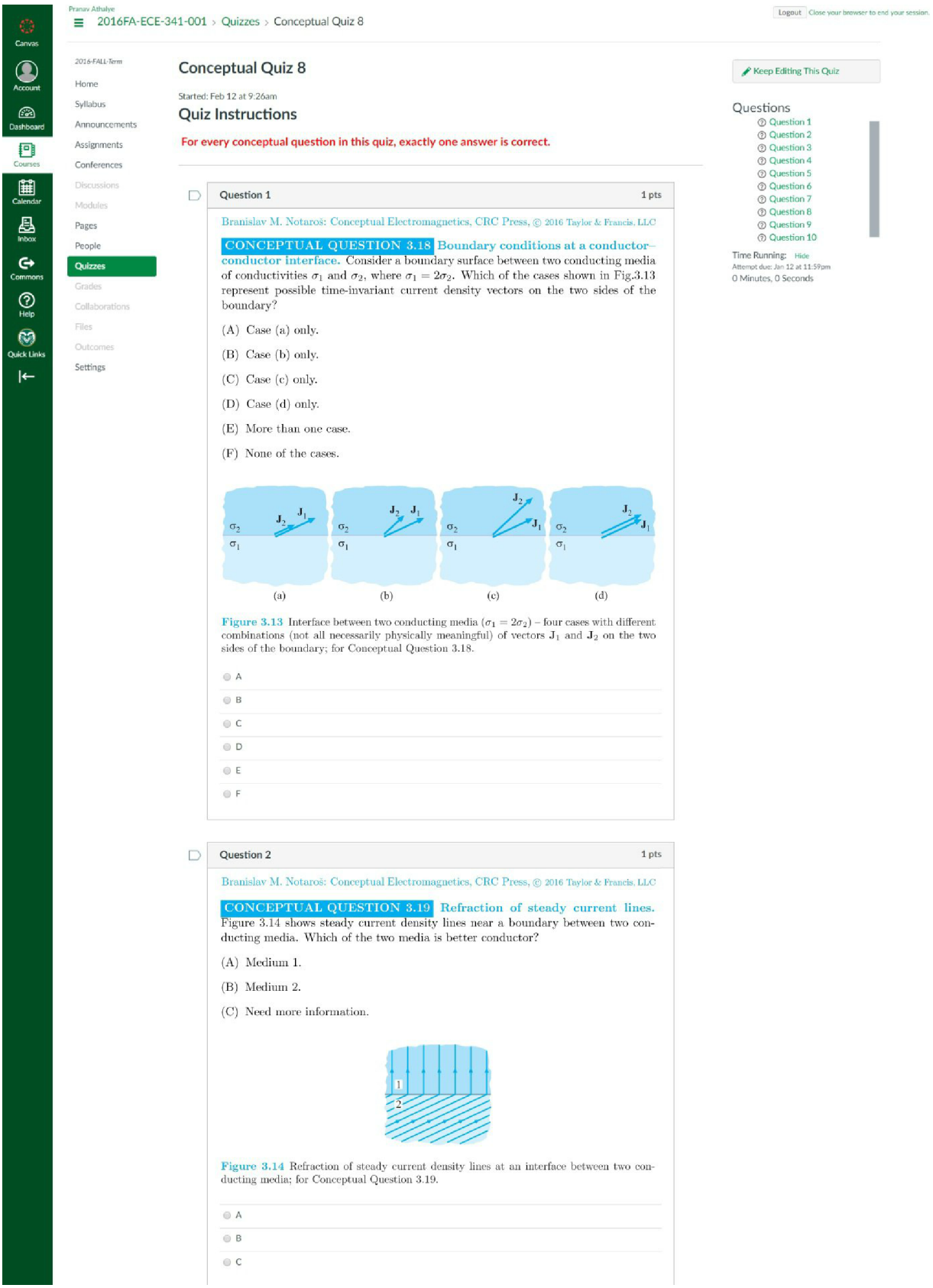


**Fig. 1: Portion of a sample class pre-work conceptual quiz in Canvas as seen by students.**

instruction semesters with nearly twice as many lecture classes. This is consistent with reports by Mason et al.[4].

**Table 1: Summary of student performance on final exam under traditional and partially flipped pedagogies.**

| Final Exam | | | |
|---|---|---|---|
| | Traditional Classroom 2012 | Traditional Classroom 2013 | Partially-Flipped Classroom 2016 |
| # of Students | 41 | 52 | 83 |
| Percent Scoring 65 or More on Exam | 76% | 71% | 82% |

## IV. Conclusions and Future Work

This paper has proposed using Conceptual Questions to assess class pre-work and enhance student engagement in electromagnetics learning studio modules, in the junior year of the electrical engineering program. Overall, this is one of the most extensive attempts to use such questions in the electromagnetics area, and in practically all ECE areas. The use of Conceptual Questions in class pre-work enabled an implementation of a partially flipped classroom instruction of electromagnetics. The preliminary results indicate that this is a step in the right direction, toward considerably improving students' learning, mastery, attitude, success, and satisfaction.

This is a work in progress and the results of this effort and study are not conclusive. As our future work, collection of more data is necessary, and more standardized results will allow for a more veritable conclusion. In addition, an even-point Likert scale survey will be established similar to those by Johnson[8]. For the future LSM/KI realizations, in order to ensure sustained improvement, several changes based on lessons learned will be incorporated into upcoming offerings of the electromagnetics course. At a more global level, the Conceptual Questions platform will be further developed, integrated, and promoted as a modern tool and environment for instruction, learning, and assessment.

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