The Inverted Engineering Classroom: An Analysis of the Impact in a First Year Engineering Program

Noemi V. Mendoza Diaz, P.K. Imbrie and Amber Muenzenberger
Texas A&M University, nmendoza@tamu.edu, imbrie@tamu.edu, atmberger@tamu.edu

Abstract – The inverted/flipped classroom, is a pedagogical approach where students “gain first exposure to new material outside of class, usually via reading or lecture videos, and then use class time to assimilate knowledge, perhaps through problem-solving, discussion, and debates. In terms of Bloom’s revised taxonomy, students are doing the lower levels of cognitive work outside of class while focusing on the higher forms of cognitive work in class where they have the support of their peers and instructor” (Center for Teaching, Vanderbilt University). Adopted by many disciplines, engineering lends itself to this new approach because traditionally the learning of engineering involves heavy practice-like experiences; meaning higher levels of learning.

The College of Engineering at a large Southwestern University has recently adopted the inverted classroom in its first-year engineering program. In combination with other structural changes in this first-year engineering program, the implementation of the inverted classroom is expected to positively influence the way engineering has been traditionally introduced to students at this University. This study presents an analysis of learning analytics from a course management system, as well as self-reported data from students’ surveys to research the impact of the first semester of implementation during the 2013 fall semester.

Time invested by students using the online interface to gather both self-reported and actual time spent on the modules, as well as performance in quizzes and in-class activities, are correlated with assessments, grades, and course objectives. are presented in this study.

Index Terms – Inverted/Flipped Classroom, Learning Analytics, Introduction to Engineering

INTRODUCTION

The inverted/flipped classroom is a relatively new pedagogy that is gaining attention within STEM (Science, Technology, Engineering, and Mathematics) fields. Recently, a number of higher education institutions have adopted the model and are studying its effectiveness on student learning outcomes as well as the adoption’s impact as part of the institutional system. Engineering education scholars and practitioners are not exempt from this trend as evidenced by the numerous engineering education conference proceedings on this topic (e.g., Bishop and Verleger, 2013; Lin, Imbertson and Moore, 2014).

Bishop and Verleger (2013) conducted a comprehensive review of research on the flipped classroom (Table 1 summarizes the 24 studies). It is noticeable that most studies were based on subjective opinions or informal assessments in a post-test fashion. According to their findings, the opinions among students across studies were positive, especially in terms of the videos over reading materials as the flipped classroom strategy. The incorporation of pre-class quizzes improved the engagement with the materials before class, and students liked the interactive class time. In terms of student performance, there was a positive impact reported, which provides an advantage over the traditional mode of teaching.

A year after this review, a new search of studies published revealed similar trends (Enfield, 2013). Enfield conducted a survey of perceptions of the flipped classroom among undergraduate students in the Cinema and Television Arts Department at California State University Northridge (CSUN). Student’s responses were grouped in top, middle, and low performing students. Interestingly, low-performing students tended to find the videos more helpful, less engaging, and more difficult than their top counterparts. Also, interestingly, while low performing students were more likely to watch the videos because of the quizzes, top performing students believed that the content of the class was going to be more useful.

Another team of researchers (Love, Hodge, Grandgenett and Swift, 2014) examined two sections of a linear algebra course at the sophomore level. They used a control group and compared common exam scores with that of the flipped classroom. They found significantly greater averages in the flipped classroom. They also conducted a survey of perceptions finding that students had a positive attitude towards the flipped classroom, felt more socially comfortable, and agreed that explaining a problem or idea helped them develop a better understanding.

Talley and Scherer (2013) studied the effect of flipped classroom instruction in a Physiological Psychology course with psychology students. Comparing student’s performance between the flipped classroom semester and the previous year’s performance, the researchers found a significantly higher performance level for students taking the flipped classroom. The researchers also reported an overall positive attitude of students. Students’ achievement and attitude were also examined by Davies, Dean and Ball (2013) in a flipped college-level information systems spreadsheet course. The study provides compelling evidence of the efficacy of the flipped approach over both the regular and simulation-based...
approaches of instructions. Wilson (2013) analyzed student performance and attitudes in a college level statistics course. The study concluded that students course grade were higher for flipped methods of instruction. In addition, students’ perceptions of their learning were improved, including their recommendation for this type of learning.

Kecskemety and Morin (2014) studied students’ perceptions in a first-year engineering course found that: 1) students who had experienced previously experienced an inverted classroom style instruction had a slightly more favorable opinions of an inverted classroom than their counterparts and 2) students reported decreased preference in the inverted classroom and increased preference in the traditional lecture-based classroom. Talbert (2014) examined students’ perceptions in a Calculus course, finding positive attitudes in students’ direct input when requested to voice their opinions. Other researchers (Lape, Levy, Yong, Haushalter, Eddy, and Hankel, 2014) examined content assessments and students’ attitude in treatment and control groups in engineering and mathematics undergraduate courses. They found no gains between the flipped and the traditional classes as well as no significant better students’ perceptions.

Table 1. Published Studies of the Flipped Classroom (Source: Bishop and Verleger, 2013)

<table>
<thead>
<tr>
<th>Study Class</th>
<th>Grade</th>
<th>In-Class Activities</th>
<th>Out-of-Class Activities</th>
<th>Treatment</th>
<th>N.</th>
<th>N.</th>
<th>Instrument Type</th>
<th>Test</th>
<th>Study Class</th>
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<tbody>
<tr>
<td>Kees(2014)</td>
<td>E</td>
<td>SGA</td>
<td>VL</td>
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<td>O</td>
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<td>Brightman(2014)</td>
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<td>Talbert(2015)</td>
<td>U</td>
<td>SGA</td>
<td>VL</td>
<td>7</td>
<td>O</td>
<td>O</td>
<td>X</td>
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<tr>
<td>Garcia-Martinez(2015)</td>
<td>Fr</td>
<td>HW/SA</td>
<td>VL</td>
<td>20/60/10</td>
<td>O</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Tol(2014)</td>
<td>Jr</td>
<td>VL/Q</td>
<td>74</td>
<td>O</td>
<td>X</td>
<td>X</td>
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<td>Zipper(2015)</td>
<td>U</td>
<td>SGA</td>
<td>VL/Q</td>
<td>77</td>
<td>O</td>
<td>X</td>
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<tr>
<td>Directions(2015)</td>
<td>U</td>
<td>SGA</td>
<td>VL/Q</td>
<td>125</td>
<td>O</td>
<td>X</td>
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</tbody>
</table>

Figure 1: How I flipped my classroom. (Source: Williams, 2013).

EDUCATIONAL SETTING
Approximately 3,000 entering engineering students are required to take a 2 credit hour, 2 course sequence, common introductory engineering course. The course presents concepts in: design, problem solving; algorithmic thinking; teaming, project management; and other engineering fundamentals. Using Brame’s work as the foundation for the course design, the first year faculty designed the course to introduce low-level engineering concepts using video modules and created a series of in-class activities and assessments to achieve higher order thinking among first year engineering students. The faculty created modules as opposed to videos, as the modules allowed for assessments and activities that could not be achieved with a video. Each module was approximately 30 minutes long, where: 1) there was no more than 10 minutes of continuous talking; 2) there were worked-out examples and exercises for students to complete; 3) each module had self-assessment questions to re-direct progress; and 4) the modules were rendered using voice synthesisization.

Students were able to use the module assessments to determine their individual level of understanding on these low-level concepts prior to class. At the same time, faculty were able to use the module analytics, which were reported by the use of SCORM, to evaluate the student’s level of understanding prior to in-class sessions. Prior to class, students were also able to submit questions on the modules. The SCORM analytics and student questions were then used to present additional information prior to starting the in-class activities. The faculty created modules as opposed to videos, as the modules allowed for assessments and activities that could not be achieved with a video. Each module was approximately 30 minutes long, where: 1) there was no more than 10 minutes of continuous talking; 2) there were worked-out examples and exercises for students to complete; 3) each module had self-assessment questions to re-direct progress; and 4) the modules were rendered using voice synthesisization.

THEORETICAL PERSPECTIVES
The theoretical basis in which authors explain the pedagogy of the flipped classroom is varied. Common to all is the problem-based, collaborative active learning that occurs in the classroom (Brame,2014). Brame, explains the prior learning that occurs outside the classroom as that of factual knowledge, falling within basic levels in Bloom’s taxonomy. Brame also states that it is through the incorporation of in-class activities, that knowledge develops into higher order thinking with a component of meta-cognitive learning, where students are able to monitor their own learning. Figure 1 (Williams, 2013) presents a comparison, in terms of Blooms Taxonomy, between a traditional model of classroom instruction to that of a flipped model of instruction. Thus the ultimate motivation for using a flipped instructional style is that students learn low level concepts on their own, prior to class. Classroom time (face-to-face time) is then used to engage students in higher levels of thinking/learning with the faculty (or other help) is readily available to clarify conceptual misunderstandings.
in-class teams to applying the knowledge gained from the modules.

**RESULTS**

To be presented is the time invested on the modules by students (both self-reported and that measured by the course LMS) to evaluate performance on quizzes and in-class activities.

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