The Inverted Classroom in a First-Year Engineering Course

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Introduction

Several authors have explored the value of implementing an inverted, or flipped, classroom model.[1,2] The inverted classroom "flips" the in-class and out-of-class activities, often by moving the lecture content before class and working on homework and hands-on activities during class time.[1] It is often referred to as a transition for the instructor from being a "sage on the stage" to a "guide on the side".[2] The inverted classroom approach has become increasingly common with the improvement of online educational resources, which are often considered a critical component.[3,4,5] Faculty have described experiences implementing the flipped classroom, mostly positive.[6,7,8] However, little has been reported regarding the effectiveness of the inverted classroom in a first-year engineering setting.

First-year engineering classrooms would appear to lend themselves well to the inverted classroom approach for several reasons. First, most students do not have previous post-secondary experience. Thus, they enter the course with fewer expectations and may be less likely to regard the inverted classroom as different or strange. Second, during this formative period of the students' engineering education, the model can potentially increase the one-on-one interactions students have with faculty and teaching assistants. These one-on-one interactions are also an efficient use of faculty resources and contact time, when first-year engineering programs are often strapped for both. Third, due to the requirement that students arrive at class prepared, the inverted approach strongly encourages students to develop the kinds of life-long learning skills that will serve them well in future coursework.

Seeing these apparent advantages, The Ohio State University's first-year engineering program implemented the inverted classroom approach in its engineering fundamentals classes beginning in the fall semester of 2012. The goal of the inversion was to make better use of classroom and staff resources. Several other courses in the unit had severely limited contact time with the students, due to the institution switching from quarters to semesters. In order to maintain a consistent instructional strategy across the unit, all courses were encouraged to adopt the flipped model. The transition from quarters to semesters puts some limitations on the evaluation of this implementation, as will be discussed below.

The purposes of this paper are to describe the inverted classroom model as implemented in the honors engineering fundamentals courses at Ohio State in the fall of 2012 and to examine the effects of this new format on student learning. Three questions will be examined: 1) How does student performance under the inverted classroom model compare to previous years' students who learned in a more traditional classroom? Specifically, would the relocation of material traditionally covered in lecture to a pre-class assignment negatively impact student performance? 2) Did the chosen implementation of preparation and application activities improve student performance? 3) Which methods of preparation did the students find the most beneficial?

The following section will detail the classroom structure for the honors engineering fundamentals program and the chosen inverted classroom approach will be explained. The

subsequent sections will discuss the results pertaining to the three aforementioned questions. Finally, recommendations for future work will be given.

Methods

Classroom Structure

The course met for three 125-minute sessions per week and for one 125-minute laboratory experience per week. While the inverted approach was applied to both the classroom and laboratory components, further discussion of the laboratory component is beyond the scope of this paper. The classroom experiences were designed studio-style, with one faculty member and two undergraduate teaching assistants; seating arrangements encouraged interaction in groups of four and included a desktop computer for each seat.[9] Thirteen sections of the course were offered, each containing approximately 36 students

This course was the first in a two-course sequence and focused on problem solving via computer programming in MATLAB and C/C++. Additional course topics included engineering ethics, technical communication, Microsoft Excel, and engineering design.

Inverted Classroom Approach

Each day's work was divided into two primary components: preparation and application (Table 1). The preparation component was to be completed prior to the beginning of class. Each preparation assignment consisted of some combination of the following: watching videos, reading book sections, completing tutorials, or working problems. A breakdown of the percentage of preparation activities of each type is shown in Figure 1. Each preparation activity was evaluated for completion in some way. Most days this took the form of an online quiz graded immediately by the online course management system (http://carmen.osu.edu). The questions were constrained to the lower Bloom's Taxonomy levels, including Remembering and Understanding, and served mostly to evaluate whether the students had completed the preparation assignment (Table 2).[11] For some preparation activities, such as working problems and completing tutorials, the students turned in the results from their preparation, such as a graph produced while completing a Microsoft Excel tutorial. Similar to the quizzes, these activities focused on basic skills that could easily be acquired without the instructor's presence.

Table 1 : Schedule for a typical inverted class day

Before Class	In Class	After Class
preparation activity: reading, video, tutorial, or problem(s) evaluation: online quiz or turned-in solution	short lecture activities begin application assignment(s)	finish application assignments prepare for next class

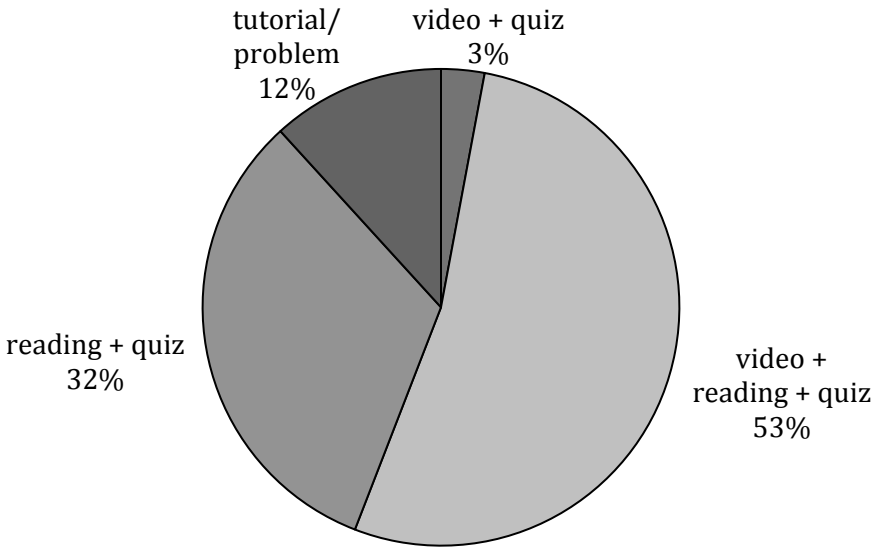

Figure 1: Percentage breakdown of preparation activities (number of activities in category/total number of activities*100%)

Table 2: Sample online quiz question set for the preparation activity

Questions	Answer Choices
Select all commands that will properly get a character from the keyboard (stdin), where the variable declaration is: **char ch;**	ch = getchar();
	ch = getc();
	getchar(ch);
	ch = getc(stdin);
Which of these commands can be used for writing a character to a file where the variable declarations are: **char ch;** **FILE *fileoutptr;**	putchar(ch, fileoutptr);
	putc(fileoutptr, ch);
	putchar(fileoutptr, ch);
	putc(ch, fileoutptr);
In C/C++, which of the following format specifiers is used for **float** variables?	%d
	%i
	%c
	%f
Which of the following scanf commands will properly read three inputs from the keyboard (stdin) into variables a, b, and c, where the variable declarations are: **float a; int b; int c;**	scanf("%d%f%f", &a, &b, &c);
	scanf("%d%f%f", a, b, c);
	scanf("%f%d%d", a, b, c);
	scanf("%f%d%d", &a, &b, &c);
In C/C++, which of the following format specifiers is used for **int** variables?	%f
	%c
	%s
	%d

Once inside the classroom, the application phase began as students received a brief lecture emphasizing important points from the reading. A typical lecture was approximately 15-20 minutes. If the preparation activity involved an online quiz, instructors were encouraged to review their students' performance and address any points of perceived confusion during this time. Furthermore, students were encouraged to ask questions that arose during the preparation

activity. On some (albeit rare) occasions, students would contact the instructor prior to class to request that a particular topic be addressed in class.

Following the brief lecture, the students began the application activities. These activities included ungraded in-class activities, graded assignments due at the end of class, and graded assignments due at a later time. The application activities were intended to expand on the preparation activities (Figure 2) and reach higher levels of Bloom's Taxonomy, such as Applying, Analyzing, and Creating[10] Where a preparation assignment might ask questions about programming, an application assignment would typically require the student to create a program to accomplish a certain task. During the class period, the faculty member and undergraduate assistants roamed the room, answering questions, providing feedback, and checking student progress.

Problem Statement
You are to write a program that prompts the user for a distance in feet (ft) and converts it to several other distance units. The conversions are listed below:

[mi] = [ft] x 1/5280	[in] = [ft] x 12	[m] = [ft] x 0.3048
[nmi] = [ft] x 381/2315000	[ftm] = [ft] x 1/6	

Figure 2: Excerpt from the application assignment associated with the preparation quiz from **Table 2**

One important consideration during course development was how to distribute the points associated with each component of the course. To provide the students with sufficient incentive to complete the preparation activities, yet also recognize that these activities were a first attempt at the subjects, the following grade distribution was used (Table 3). This grade distribution was similar to the distribution used in similar courses prior to the inversion of the classroom, with the majority of the 10% devoted to preparation assignments pulled from the weekly quizzes (6%) and the midterm exams (3%).

Table 3: Grade distribution for the course, with preparation assignments worth 10% and application assignments worth 20%

Preparation Assignments	10%	Lab Practical	3%
Application Assignments	20%	Weekly Quizzes (Not Preparation)	6%
Extra Weekly Assignments (Bonus)	3%	Midterm Exams	20%
Lab Preparation & Reports	18%	Final Comprehensive Exam	15%
Design Project	5%	Anonymous Journals	3%

Results and Discussion

Performance Compared to a Previous Year

The first evaluation of the effectiveness of the new classroom setup was a comparison of student performance on a set of programming questions used on the comprehensive final for both the first year under the inverted classroom model and the last year under the traditional model. The final exam was never released to the students; thus, several questions were re-used.

Only seven sections from each year that were taught by the same set of instructors were included in the analysis, for a total of 492 students' grades. Since the exam grades did not form a normal distribution (see Figure 3), a Mann-Whitney test was performed to determine if the two distributions were different. The analysis did not indicate a significant difference between the test scores of the two years ($p=0.17$). This indicates that the change in approach did not have a negative impact on student learning of programming.

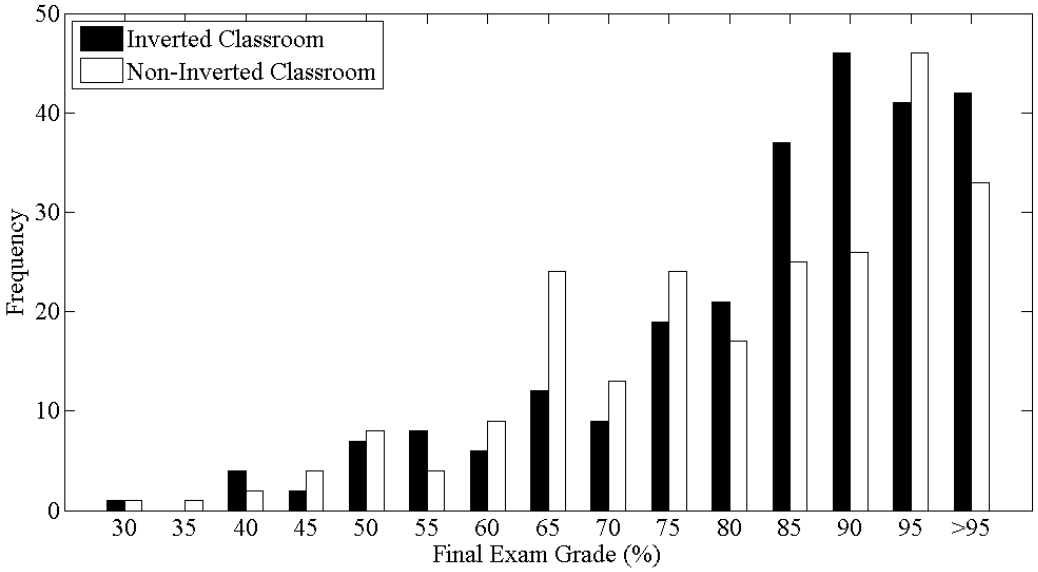

Figure 3: This figure illustrates the comparison of student grades under the inverted classroom approach (N=255) to performance under a traditional lecture-based classroom (N=237) on identical final exam questions.

The goal of the classroom inversion was not necessarily to improve programming ability, though such a result would have been welcome. Rather, for the first implementation of the new approach where the topic introductions were moved outside of the classroom and lecture time was decreased in class, it is encouraging that the students did not experience a decrease in exam performance. This suggests additional time spent in class on application activities must have successfully offset the decreased lecture time. Additionally, the previous programming course was the second quarter of a first-year sequence, while the new course was offered first semester. Therefore, it is possible that, in the inverted class, some students who would have been dismissed from the honors program or otherwise would have left under the previous system may have affected the results. Furthermore, students had less time to learn successful study skills and adjust to the college experience. Thus, it was considered a positive outcome that the final exam grades did not decrease.

Effect of Preparation and Application Activities on Student Performance

Next, the effect of the preparation and application activities on student performance in the course was examined using the Pearson product-moment correlation coefficient. For this analysis, all students who completed the course were included (N = 473). The first test considered whether student grades on the preparation activities was correlated to grades on the application activities

(Figure 4). It was found that the preparation and application performances were strongly correlated ($r = 0.742$, $p<0.01$).

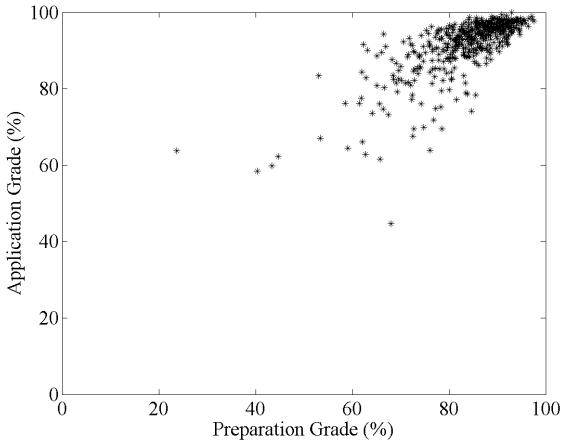

Figure 4: This graph shows the relationship between student grades on the application assignments (%) to student grades on the preparation assignments (%) (N=473). A Pearson product-moment correlation test found that they were strongly correlated ($r=0.742$, $p<0.01$).

Next, the sum of preparation and application grades was compared to the quiz grades and the sum of the midterms and final exam (Figure 5). These pairings also suggested a strong correlation ($r=0.556$, $p<0.01$ and $r=0.521$, $p<0.01$, respectively).

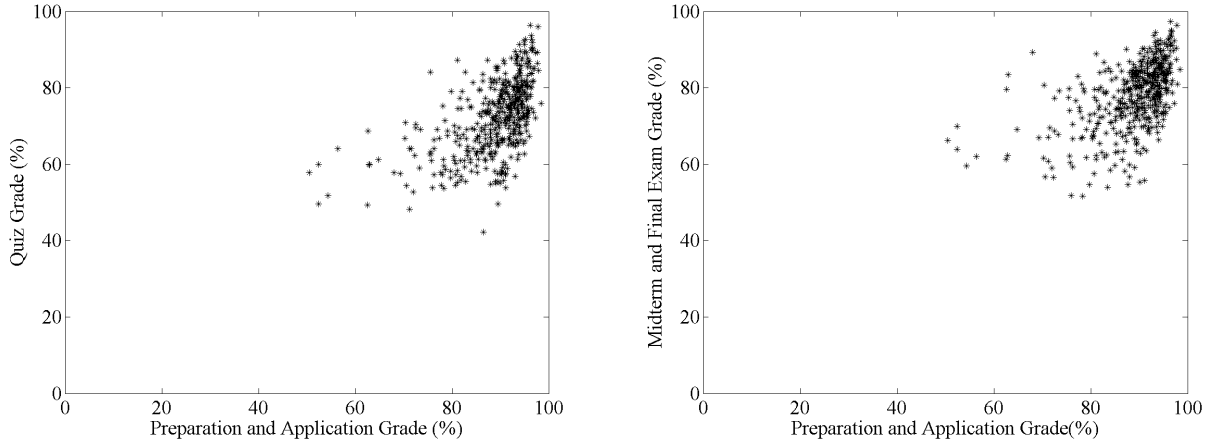

Figure 5: This figure compares the sum of the preparation and application assignment grades (%) to two measures: 1) quiz grades (%) (left), and (2) the sum of the two midterm exam grades and one final exam grade (%) (right) (N=473). The Pearson product-moment correlation test suggested strong correlations for both ($r=0.556$, $p<0.01$ and $r=0.521$, $p<0.01$, respectively).

The results of the first comparison, between preparation and application activity performance, suggest that the preparation activities were effective in introducing the material required to successfully complete the application activities. They also show that the preparation activities are a high predictor in course performance, indicating that these grades could be useful in identifying struggling students prior to exams.

The results of the second and third comparison, between the combined preparation and application activity performance and the exam and quiz performances, suggest that the activities

included in this course development were effective in teaching the material required for the students to perform well on the exams and quizzes.

Preferred Preparation Activities

Finally, students' preferred preparation activities were investigated. The students in the honors program completed a weekly anonymous journal to provide feedback to the program and respond to a variety of prompts.[11] During the 12th week of the 16-week semester, students were provided with the following prompt: "During this term, you have been given a variety of assignments to do in preparation for upcoming classes: reading, watching videos, completing tutorials, working problems, taking quizzes. Which of these styles have been the most helpful to you and why? Which have not been as helpful and why? Do certain types of preparation work fit better with particular topics? If so, please give some examples of particularly good or bad 'fits.'"

A representative sample of 150 students was analyzed by counting the number of positive mentions of each preparation activity. Despite the prompt asking students which topics were not as helpful, many students who listed their preferred preparation assignments did not list which preparation assignments were less helpful. This made an analysis of positive mentions more representative than an analysis of negative mentions. The results are shown in Figure 6. The quizzes received 83 positive mentions (55% of responses), the highest of the categories. The videos and reading assignments received a high number of mentions, at 67 (45%) and 48 (32%), respectively. Solving problems received the next highest number of mentions, at 36 (24%), followed by tutorials at 18 (12%). Only 2 students (1.3%) stated that none of the preparation activities were helpful.

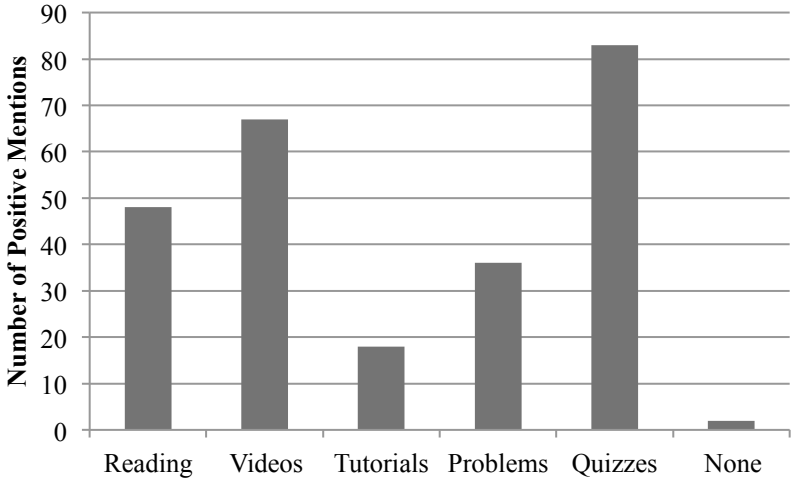

Figure 6: The number of positive mentions of each preparation activity style for a representative sample of 150 students (note that each student could mention multiple helpful activities)

There appeared to be some correlation between the frequency of the preparation assignments and the number of positive mentions a category received. As shown in Figure 1, the majority of the assignments included a video, a reading, and a quiz. These categories also received the most positive mentions. Thus, it is difficult to differentiate from the statistics whether these

preparation activities were mentioned the most because they were the best or because they were used the most frequently. However, the fact that they were mentioned this frequently in a positive light indicates that the students found them to be of particular value in their learning.

The most unexpected result was the number of students who identified quizzes as helpful, often even the most helpful preparation. Students stated that the quizzes helped give them motivation to complete the other components of the preparation, and allowed them to focus on the important topics. One student stated, "Doing the quizzes before class have been the best for me because it forces me to look at the book and get ready for the class. I feel that the quizzes work the best in all areas." Another student wrote, "…I found the quizzes to be most helpful. I thought they did a good job of narrowing in on the topic that would be covered." A few students did mention that they did not like the quizzes, writing "I think the quizzes have been the least helpful because it is difficult to be tested on something you have barely been taught" and "[i]f there was a quiz, I just tended to look for the answers instead of reading the entire material."

This result was significant because it addressed one of the major concerns in the inverted classroom model: instructional staff time commitment. With at least one preparation assignment and one or two application assignments each class period, the grading load was potentially overwhelming. Since the quizzes were graded automatically by the online course management system, it significantly reduced the amount of grading. The student preference for this tool, combined with the effectiveness of the preparation activities demonstrated earlier in this section, suggests that these automatically graded quizzes were an efficient solution for evaluating preparation activities.

The students were somewhat polarized on the videos and reading assignments. One student wrote, "The most helpful for me was reading the book before class…the videos were not helpful to me, and I honestly quit watching them after about three weeks," while another wrote, "Reading is always least preferred, but that's just how it is because it makes me fall asleep… Videos of programming and how to make sample code has [sic] been very helpful." Some students believed they benefitted from both, including one student who said, "reading the book and watching the videos are necessary for learning the material."

The primary complaints for the reading were that there were components of the reading that were not explicitly used in class and that the books were confusing. The primary complaint for the videos was that they were long. The former suggests that choosing a more engaging book or one with slightly different emphasis may improve student acceptance of the reading assignments. However, there seems a higher potential for improving the videos by decreasing their length from the approximately 20 minutes that they take in their current state.

Working problems and completing tutorials were mentioned somewhat less than quizzes, videos, and reading, though this may be due to the fact that they comprised a relatively small percentage of the preparation activities. Those students who did mention them preferred their hands-on nature, stating, "All the completing tutorials and working problems pre-assignments have been the most helpful styles to me because it made me actually want to do the pre-assignments and gave me material to look back on later that I could actually use as guidance and a helpful tool."

Relatively few students (1.3%) stated outright that they found none of the preparation work helpful. The primary complaints were "there is just so much work" or "it was really easy… so they were useless." The fact that these statements were so rare suggests that the first-year engineering may be a good setting in which to introduce the inverted classroom approach. The positive attitude percentage is similar to, or even higher than, the figures given in many reports in the literature.[1,6,7,8]

Conclusion and Future Work

In summary, the first-year engineering honors program at Ohio State implemented the inverted classroom approach as part of switching from the quarter system to semesters. Students were required to engage in lightly-assessed preparation activities before each class and to participate in application activities during class time. In-class lecturing was minimal. First-semester students learning computer programming in the first implementation of this approach performed no differently from those who had taken a similar class as second-quarter students the year before.

An analysis of student performance in the course revealed that scores on the preparation work were strongly correlated with scores on the application work, quizzes, and exams. The conclusion drawn from this is that the pre-class work met the instructional staff's goal of preparing the students for the deeper learning that followed. Student reports on the preparation work support this conclusion; only 1% reported that they saw no value in the pre-assignments. However, it is difficult to isolate the likely fact that students who work harder do the pre-assignments and are more likely to do well on the application activities and exams. Future work should attempt to isolate this effect, possibly through a control group or a self-reported "time spent" on the course.

Student reports also revealed that all of the styles of preparation were helpful to some significant portion of the population. The students reported the most helpful portion of the preparation work to be the quizzes, followed by videos, reading assignments, problems, and tutorials.

This paper reported the results of implementing the inverted classroom model in an honors classroom. A different team of instructors worked to flip the non-honors version of the course, and so a discussion of that experience is beyond the scope of this paper. Still, it would be beneficial to perform a similar analysis on the student performance and feedback in that course.

In response to student feedback, the staff will attempt to shorten the videos. They will also revisit the reading assignments to determine if there are ways to make the connections between the reading and in-class work even stronger. Based on student performance and feedback, the staff will continue using the inverted classroom approach, not only in this course, but also in the following course on engineering graphics and design.

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