



A Multiple Institution Investigation of Student Perceptions of the Inverted Classroom in First-Year Engineering Courses

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Introduction

The inverted classroom model has increased in popularity and its many benefits and challenges have been asserted.^{1,2} Bishop and Verleger define a flipped classroom as: “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom” (2013).³ The theoretical framework for the inverted classroom approach is based on Bloom’s taxonomy. Typically the lower-level of the revised Bloom’s taxonomy skills of remembering and understanding⁴ are completed prior to class, and the higher level Bloom’s skills can be completed in class. This model allows the lower-level skills to be completed without an instructor and by contrast the higher-level skills are completed in the classroom when instructional staff is available for guidance.

The inverted classroom model has many potential benefits that are noted in the literature. Some of these include: making effective use of class time, making good use of technology, accommodating various learning styles,^{2,5} helping students become self-learners,² fostering life-long learning skills,⁵ promoting collaborative learning⁵ and personalized learning,⁶ and increasing classroom engagement.⁶ Investigating one specific benefit, Stickel et al.⁷ surveyed students and found that the level of faculty student interaction increased with the inverted classroom model compared to a traditional classroom, which is to be expected since that is a primary goal of the inverted approach. Lifelong learning is a goal of higher education and the potential of the inverted classroom approach to improve lifelong learning makes it desirable. As Talbert says, in a traditional classroom students are unable to gain lifelong learning skills like: “... the ability to identify when one’s personal knowledge runs short and when to seek out more information, the ability to comprehend new information independently when it is south out, and the ability to monitor one’s own progression through the process of learning new content.”⁸ These are skills that an inverted classroom model has the potential to develop and expand in students.

Previous research has investigated student perceptions of the inverted classroom.^{2,6} Two of the institutions in this study have investigated the use of the inverted classroom with student preferences and perceptions⁹ and student opinions and feedback about the inverted classroom approach.¹⁰ This paper seeks to expand on that work and examine the following research questions that are focused on students’ perceived benefits and classroom approach preferences at multiple institutions: *How do students perceive that they benefit from the inverted classroom approach and what classroom approach do they prefer? Additionally, how does this change at different institutions with different approaches to the inverted classroom model?*

Methods

University and Course Descriptions

Three Midwestern institutions participated in different aspects of this study. The three universities were:

- University A – University of Cincinnati: a large, urban public university
- University B – The Ohio State University: a large, urban public land grant university
- University C – Youngstown State University: a medium, urban public university

Each institution uses an inverted classroom approach with first-year engineering students.

University A is a large university with an undergraduate student population of around 32,000. The university is a public institution which draws heavily from the surrounding area. Approximately 79% of the students come from within the state, with 14% of the student population comprised of ethnic minorities. Overall, there is a 16:1 student to faculty ratio. The College of Engineering and Applied Science currently admits approximately 1000 undergraduate students each year with a total undergraduate enrollment of around 4000 and has a similar ethnic profile to the university as a whole. Students are able to matriculate directly to a major, with approximately 15% choosing to enroll as undeclared engineering. There is a department with 9 faculty members responsible for administering the first-year engineering courses, but faculty are also assigned from the degree-granting departments.

At University A, the inverted classroom is employed in a two semester sequence of courses which are taken by all first-year engineering students and focuses on developing problem solving and computing skills. In this class, students use MATLAB to solve a variety of problems incorporating ideas from engineering, calculus, physics, and chemistry. Students watch videos on the lecture material for the week outside of class and have the opportunity to test their learning by taking a practice quiz. In lecture, students are first given a quiz to ensure that they have reviewed the lecture material, after which the remaining lecture time is devoted to solving problems together as a class, in small groups, or individually.

University B is a large university and has an undergraduate population of approximately 45,000 students on its main campus. Of these 45,000 students approximately 80% are in-state residents. The College of Engineering has approximately 7000 students with a new first-year enrollment around 1700 students. However, including non-first year enrolled students, the first-year engineering sequence has approximately 2000 new engineering students each year. Students do not declare their engineering major in the first-year. In the first-year engineering program courses the student to faculty ratio ranges from approximately 12:1 to 14.5:1 depending on the course. This student to faculty ratio in the classroom includes undergraduate and graduate teaching assistants as well. There are approximately 23 faculty who are hired solely to teach these first-year engineering courses, and about 5 additional faculty are used part time from the engineering departments.

At University B, the first semester of a two semester sequence taken by first-year engineering students, focuses primarily on computer-aided problem solving using Excel and MATLAB. The preparation component, completed before class, involves pre-class learning activities such as

videos, reading assignments, and tutorials. Student completion of the preparation activity is evaluated through an online quiz or through a short assignment submitted at the beginning of class. The application component begins in the normal class period and includes a short presentation, in-class activities, and assignments.

University C is a medium sized university with an undergraduate population of approximately 13,000. Each year the First-Year Engineering Program enrolls 200-250 new students, with ~1,000 students in all engineering programs across disciplines and ~2,700 in the entire STEM College. The First-Year Engineering Program is taught by 2 faculty and 20 undergraduate teaching assistants. The student to faculty ratio is 19.5:1. The university is in an urban setting, and 85-90% of students commute to campus. Approximately 86% of students come from within the state.

At University C, a partially flipped classroom model was implemented. As part of the First-Year Engineering Program, students take a 1 credit hour course to explore the different engineering disciplines at the institution. On a weekly basis, students focus on a different engineering discipline through a hands-on activity during class. In preparation for such activities, students were required to watch a video on line about that engineering discipline. The videos are less than 10 minutes in length and are focused on: curriculum, student involvement, and professional opportunities.

Bloom's Taxonomy and the Inverted Classroom

While a goal of the inverted classroom is to have higher levels of revised Bloom's Taxonomy occurring in the classroom and the lower levels occurring before class, the implementation of this varies across the universities. For example in preparation activities, at University A there are examples and problems in the videos that students are encouraged to try to work through before continuing to watch the videos. These activities primarily target the remembering and understanding levels of Bloom's Taxonomy and only occasionally reach the applying level. These students also have remembering and understanding level questions available through an optional practice quiz. At University B, students are mainly engaged at the remembering and understanding level through required online quiz questions before class. Occasionally, there will be a short activity or tutorial that requires applying, but these are infrequent.

In contrast, the higher levels of Bloom's Taxonomy are incorporated to the in-class activities. Lecture activities are used at University A that target the higher levels of Bloom's taxonomy, specifically applying (using concepts to solve problem), analyzing and evaluating (determining what method is best to solve the problem), and creating (writing the MATLAB program). At University B, most in-class activities are built around applying the knowledge from the preparation activities. Occasionally, there will be activities and assignments requiring analyzing and evaluating. At University B, there is a larger programming project at the end of the semester that uses the highest levels of analyzing, evaluating, and creating.

Survey Description

University A and University B gathered survey data at the beginning and end of the semester asking students to rate their perceived benefits of the inverted classroom approach on a 5 point Likert scale. While University C did not include questions about the benefits of the inverted approach, all three universities asked students at the beginning and end of the semester to select their preferred classroom approach: traditional lecture based, inverted classroom, or partially-inverted and partially traditional. The survey questions are shown in Figure 1.

<p>1. Do you know what an “Inverted” or “Flipped” classroom approach is?</p> <ol style="list-style-type: none">YesNo <p>Information</p> <p>For the remainder of this survey use the following definition of the inverted classroom approach:</p> <p>The inverted classroom model is based on the initial learning and exposure to a concept occurring outside of the classroom, before the students experience the material in-class. This outside of the classroom exposure can include reading, videos, tutorials or other learning devices or activities. The in-class time is then used to reinforce this knowledge through interactive learning activities, assignments, and projects. The amount of time spent by the instructor “lecturing” or “presenting” in the classroom setting is minimized (not the primary classroom activity) and is only used to help reinforce material, not deliver new content.</p> <p>2. I most prefer a classroom with the following approach:</p> <ol style="list-style-type: none">Traditional lecture-based classroomPartially traditional and partially inverted classroomInverted classroom <p>3. Rate the following statements on a scale from strongly disagree to strongly agree.</p> <ul style="list-style-type: none">The inverted classroom approach will let me get immediate feedback while working on homework and activities.The inverted classroom approach will not use class time efficiently.The inverted classroom approach will let my instructor focus primarily on topics that are harder to understand.The inverted classroom approach will not make good use of technology.The inverted classroom approach will make class time more engaging.The inverted classroom approach will create an active learning environment.The inverted classroom approach will help me learn topics to a deeper level than a traditional classroom. <p>4. Rate the following statements on a scale from strongly disagree to strongly agree.</p> <ul style="list-style-type: none">The inverted classroom approach will accommodate my learning style.The inverted classroom approach will personalize learning to me.The inverted classroom approach will not allow me to learn at my own pace.The inverted classroom approach will help me because I can revisit the preparation material whenever I need.The inverted classroom approach will make me feel more responsible for my own learning.The inverted classroom approach will help me become a better self-learner.The inverted classroom approach will not encourage me to learn from my peers.The inverted classroom approach will grow my life-long learning skills.
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Figure 1: Inverted Classroom Survey Questions, University A and B administered 1-4 and University C administered 1-2.

Results and Discussion

Student Instructional Approach Preferences

The first question asked students if they knew what the inverted classroom approach was and the results are shown in Table 1. It is interesting that University B had more than 80% of the students who said they did know what the inverted classroom was. Since the inverted classroom approach was explained during the first class period this high percentage was to be expected. University B also had the largest percentage of students at the end who said they knew what the inverted classroom. In this post-test, only 3% of the students said they still did not know what the approach was. University A and C were very different in that both these results only had 25% of the students indicating they knew about the classroom approach. These values increased to 81% and 61% for University A and C respectively. After computing a Pearson's chi-squared test on the data, the changes from the pre-test to the post-test were all statistically significant (p -value <0.05). Comparing the universities to one another with the Pearson's chi-squared test they all resulted in statistically significant differences except when comparing the pre-test at University A and pre-test at University C.

Table 1: Student responses to knowing what the inverted classroom approach was.

	University A		University B		University C	
	Pre-test N=681	Post-test N=231	Pre-test N=927	Post-test N=743	Pre-test N=203	Post-test N=158
Yes	25.3%	81.2%	83.7%	96.9%	26.1%	61.3%
No	74.7%	18.8%	16.3%	3.1%	73.9%	38.8%

After asking if they knew what the inverted approach was, students were provided with a broad definition of the inverted classroom as shown in the survey in Figure 1. Students were then asked to choose their classroom approach preference allowing for a traditional lecture-based classroom, a mixture of a partially traditionally and partially inverted classroom, and an inverted classroom and the results are shown in Table 2. All three universities in both pre-test and post-test had the majority of students preferring a partially traditional/partially inverted approach on the order of 70%. Looking at just the inverted classroom choice, University A reported an increased percentage of students who prefer an inverted classroom at the end of the semester, while Universities B and C both reported decreases. Universities B and C also noted an increased interest in traditional lecture-based classrooms, while University A saw this percentage decrease slightly.

Table 2: Classroom approach preferences for both pre-test and post-test.

	University A		University B		University C	
	Pre-test N=681	Post-test N=231	Pre-test N=927	Post-test N=743	Pre-test N=203	Post-test N=158
Traditional lecture-based classroom	19.5%	18.2%	11.4%	20.1%	5.9%	10.1%
Partially traditional and partially inverted classroom	72.1%	69.3%	73.9%	69.3%	67.0%	74.1%
Inverted classroom	8.4%	12.6%	14.7%	10.6%	27.1%	15.8%

Performing a Pearson’s chi-squared test with the classroom preferences found that statistically significant differences were apparent in all comparisons (pre-test to post-test, and university comparisons), except the comparisons that involved University A’s post-test. University A’s post-test when compared to the post-tests at University B and C did not result in a statistically significant difference. University A also did not have a statistically significant difference from pre-test to post-test while the other universities did.

In order to see if the students’ prior knowledge of the inverted classroom impacted their classroom preferences, Table 3 and 4 show the two different populations. Here it is interesting to see that the population reporting no knowledge of the inverted classroom at the post-test for Universities A and C had a higher percentage of students selecting it as their preferred classroom approach, than the percentage of students who were familiar with the inverted classroom approach.

Table 3: Classroom approach preference for students who indicated they did know what the inverted classroom was.

	University A		University B		University C	
	Pre-test N=173	Post-test N=188	Pre-test N=776	Post-test N=743	Pre-test N=53	Post-test N=98
Traditional lecture-based classroom	15.0%	15.4%	10.6%	19.7%	5.7%	10.2%
Partially traditional and partially inverted classroom	75.7%	73.4%	74.6%	69.4%	71.7%	76.5%
Inverted classroom	9.2%	11.2%	14.8%	10.8%	22.6%	13.3%

Table 4: Classroom approach preference for students who indicated they did not previously know what the inverted classroom was.

	University A		University B		University C	
	Pre-test N=506	Post-test N=43	Pre-test N=151	Post-test N=23	Pre-test N=150	Post-test N=60
Traditional lecture-based classroom	20.8%	30.2%	15.9%	30.4%	6.0%	10.0%
Partially traditional and partially inverted classroom	71.1%	51.2%	70.2%	65.2%	65.3%	70.0%
Inverted classroom	8.1%	18.6%	13.9%	4.3%	28.6%	20.0%

Student Perceived Benefits

The students were surveyed at University A and B to see what benefits they perceived they obtained from the inverted classroom approach. Figure 2 and Figure 3 show the mean responses to these statements along with the standard deviation. For questions that were asked in a negative way, the means shown here are reverse coded. Note, none of the responses in any of the surveys resulted in a mean value of less than 3.00 (neutral) indicating a neutral to positive view of the benefit statements.

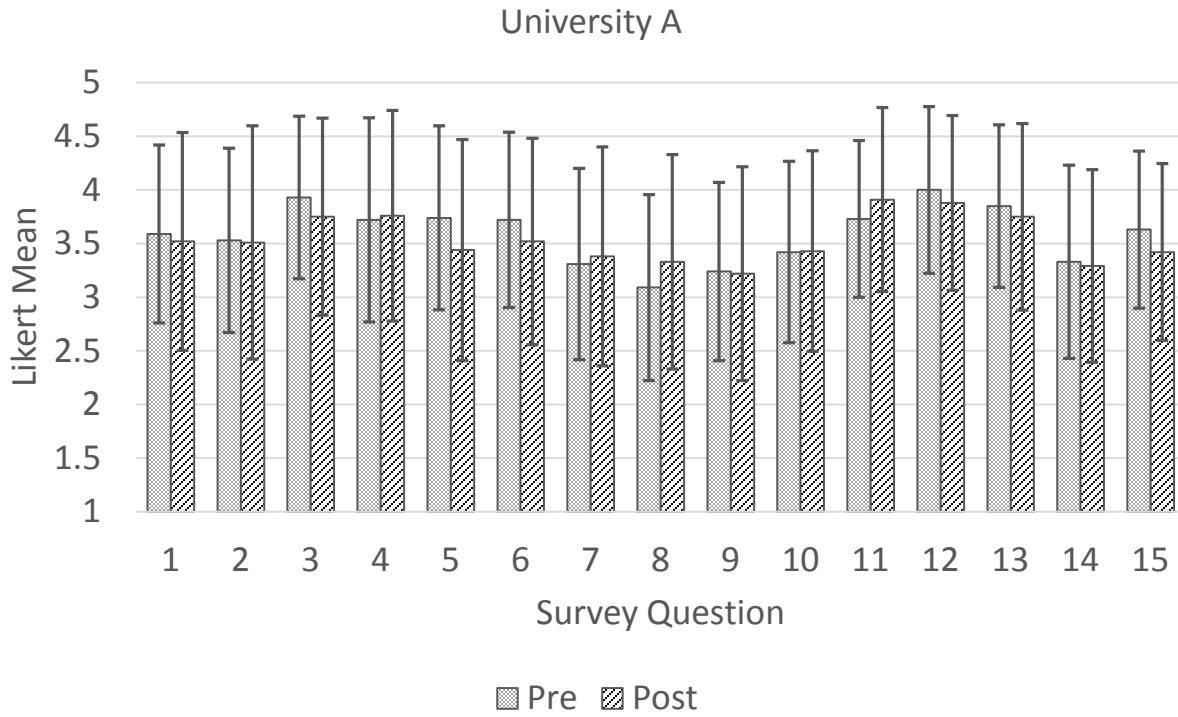


Figure 2: University A pre-test and post-test survey inverted classroom perceived benefit statement results.

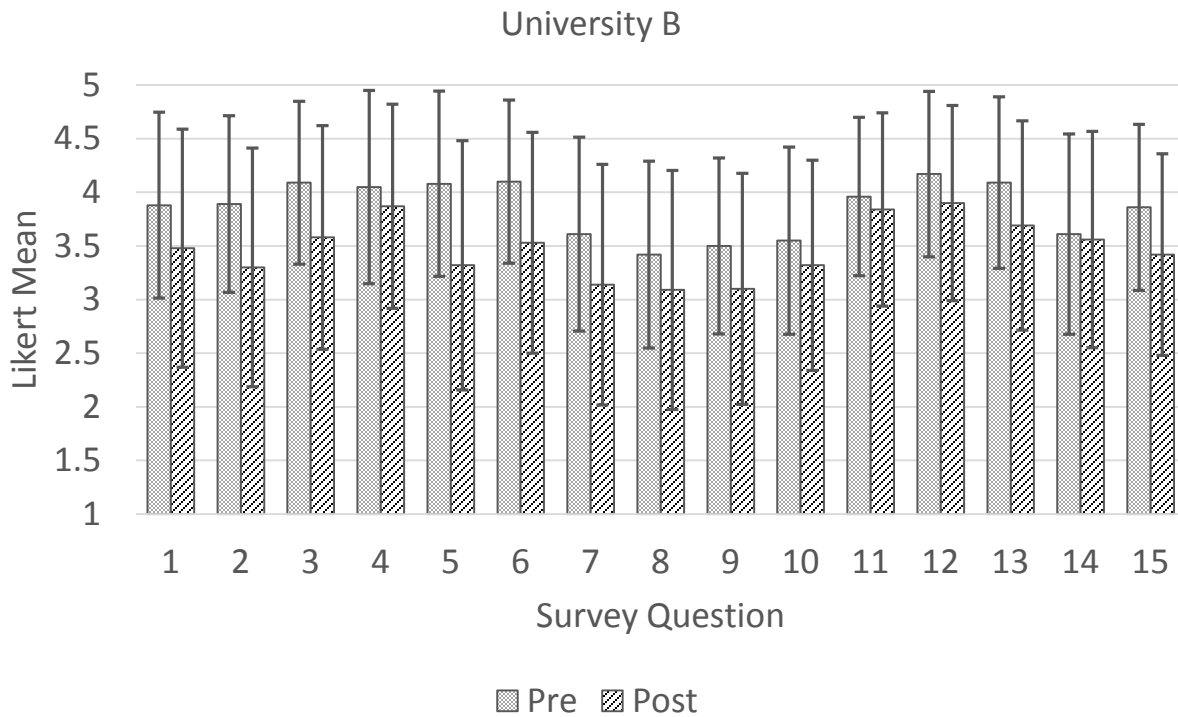
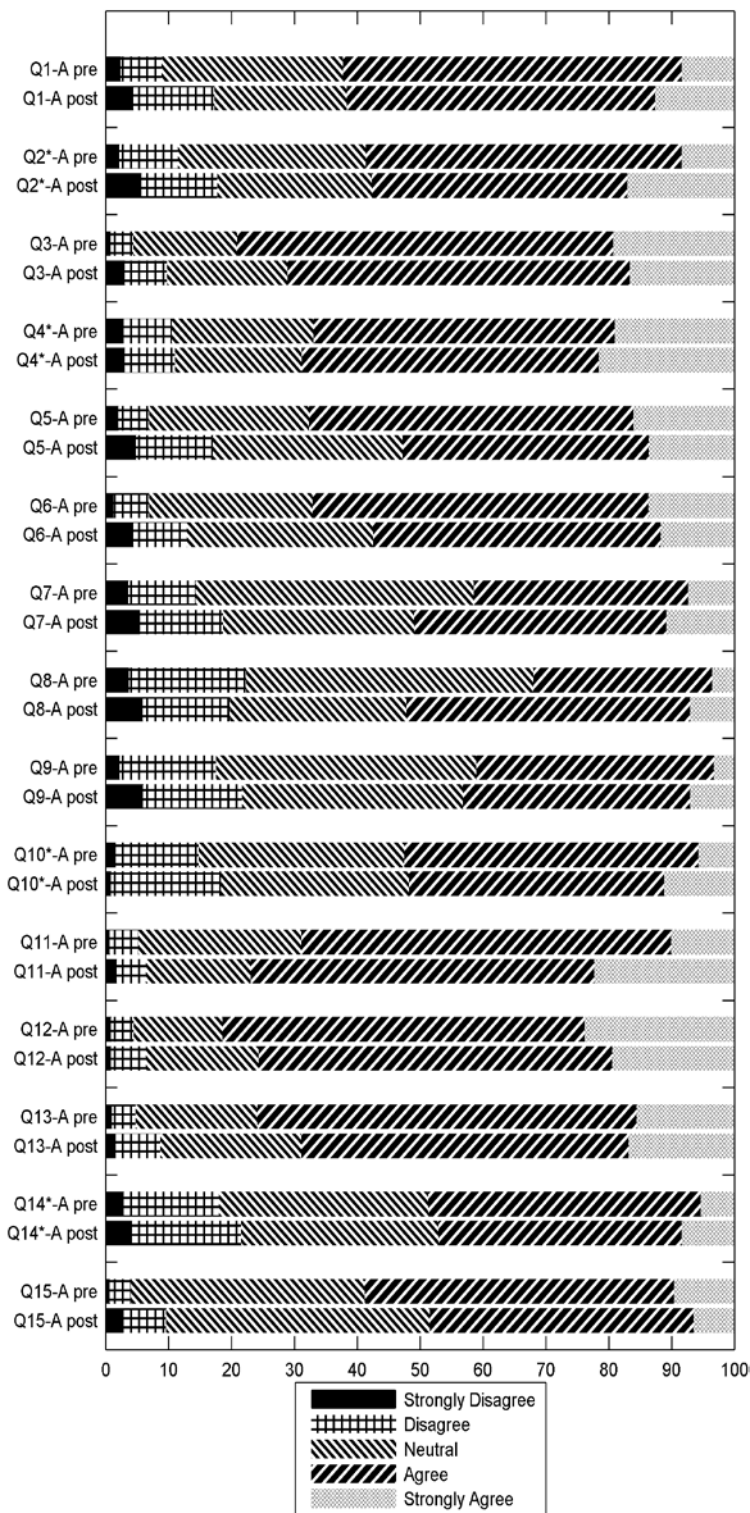


Figure 3: University B pre-test and post-test survey inverted classroom perceived benefit statement results.

In comparing the pre-test to post-test results there were some statistically significant changes. The 5 point Likert scale results were compared using a statistical test for non-normalized distributions, a Mann-Whitney U test. The pre-test and post-test results for University A are shown in Figure 4. For University A, 7 questions resulted in statistically significant differences (p-value < .05). Five of these questions exhibited a negative shift in the mean (Questions 3, 5, 6, 12, 15) whereas two questions had a positive shift in the mean (Questions 8 and 11). These two statements deal with accommodating learning styles and being able to access preparation information whenever it is needed.

The results for University B are shown in Figure 5. For University B, 14 out of the 15 questions resulted in statistically significant differences (p-value < .05). The only question to not exhibit a statistically significant difference was Question 14. In the rest of the questions all of the changes from the pre-test to post-test were negative mean changes. This indicates that the students in University B did not see increasing benefits of the inverted classroom after completing the semester.

Comparing the two University populations to each other show some differences. In the pre-test results shown in Figure 6, the two university populations had statistically significant differences with all the statements. In the post-test, however, there were only four statements that had statistically significant differences (Questions 2, 7, 8, 14). This is shown in Figure 7, with University A scoring higher with Question 2, 7, and 8 and University B scoring higher with Question 14.



The inverted classroom approach lets me get immediate feedback while working on homework and activities.

The inverted classroom approach does not use class time efficiently.*

The inverted classroom approach lets my instructor focus primarily on topics that are harder to understand.

The inverted classroom approach does not make good use of technology.*

The inverted classroom approach makes class time more engaging.

The inverted classroom approach creates an active learning environment.

The inverted classroom approach helps me learn topics to a deeper level than a traditional classroom.

The inverted classroom approach accommodates my learning style.

The inverted classroom approach personalizes learning to me.

The inverted classroom approach does not allow me to learn at my own pace.*

The inverted classroom approach helps me because I can revisit the preparation material whenever I need.

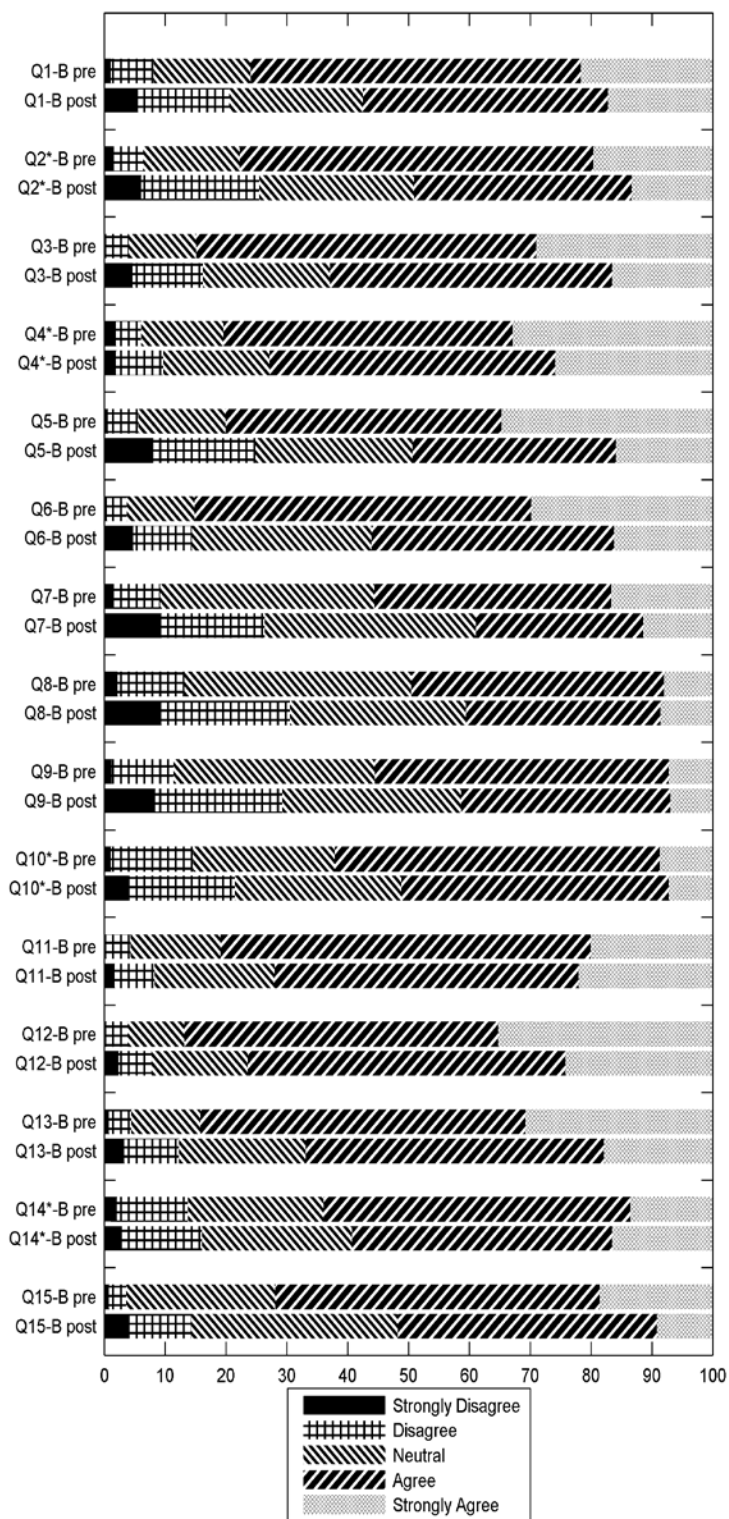
The inverted classroom approach makes me feel more responsible for my own learning.

The inverted classroom approach helps me become a better self-learner.

The inverted classroom approach does not encourage me to learn from my peers.*

The inverted classroom approach grows my life-long learning skills.

Figure 4: Perceived benefits of the inverted classroom pre-test and post-test survey results at University A. Those questions asked in the negative (indicated by *) are shown with inverted responses in the graph, as if they were asked as positives.



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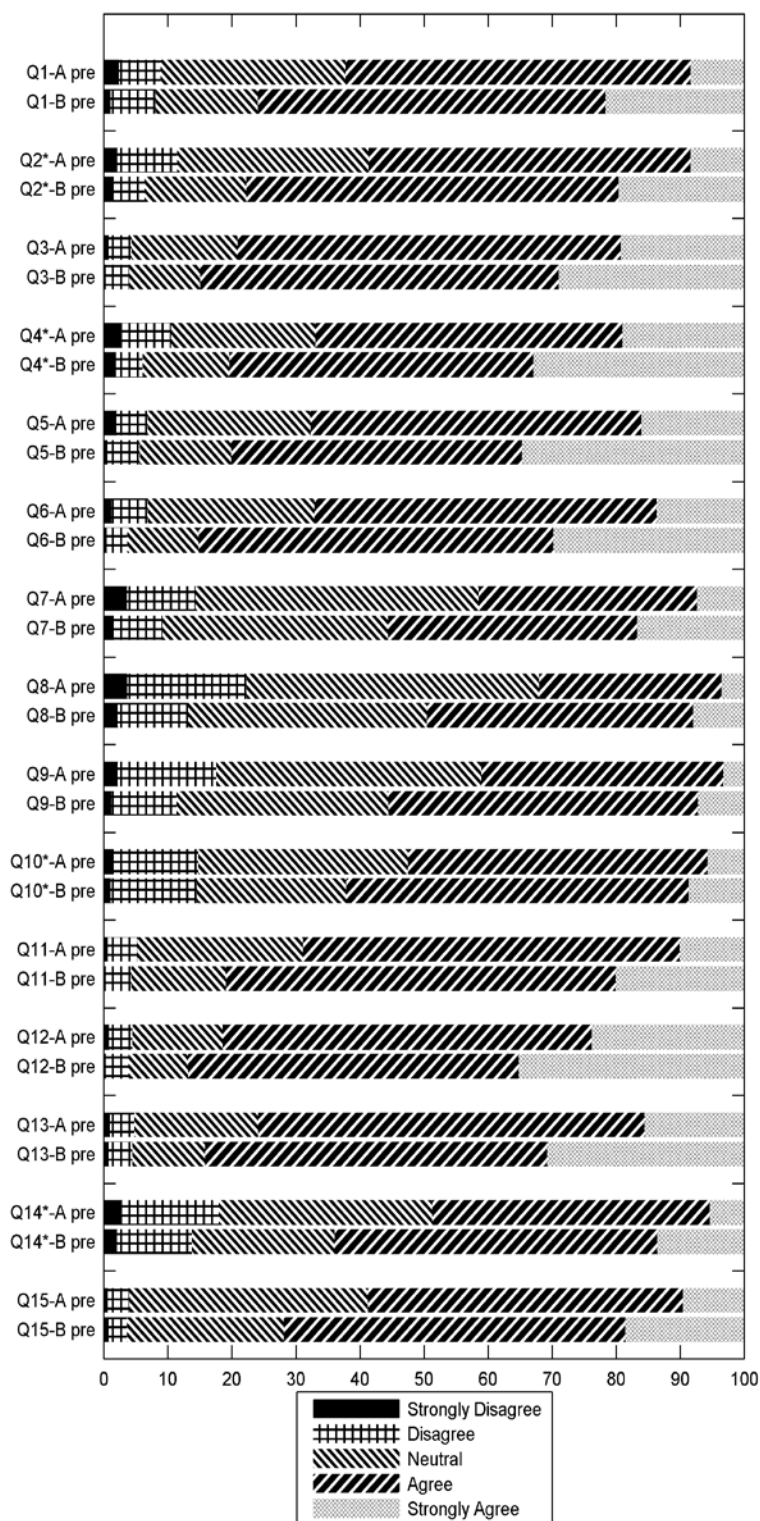
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The inverted classroom approach helps me become a better self-learner.

The inverted classroom approach does not encourage me to learn from my peers.*

The inverted classroom approach grows my life-long learning skills.

Figure 5: Perceived benefits of the inverted classroom pre-test and post-test survey results at University B. Those questions asked in the negative (indicated by *) are shown with inverted responses in the graph, as if they were asked as positives.



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The inverted classroom approach lets my instructor focus primarily on topics that are harder to understand.

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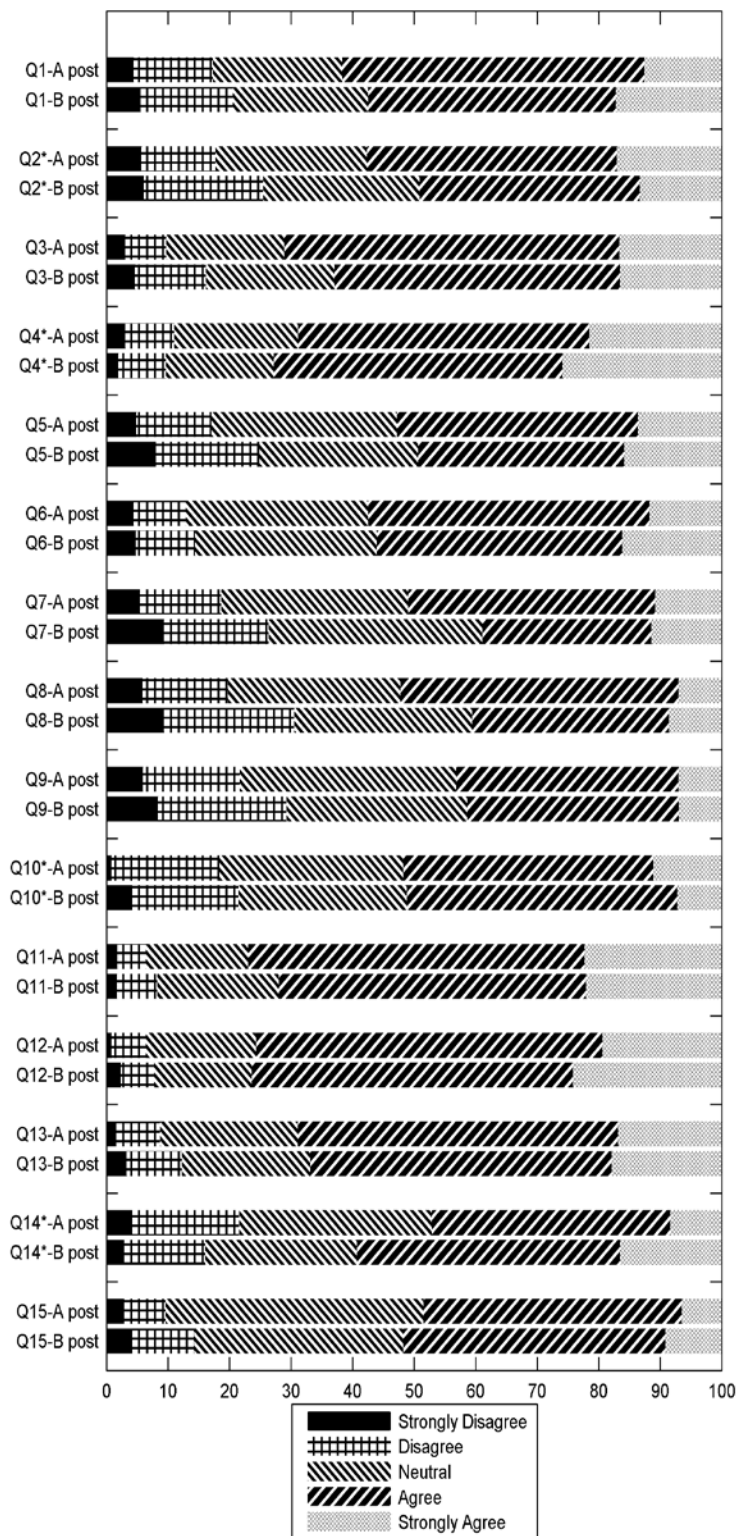
The inverted classroom approach makes me feel more responsible for my own learning.

The inverted classroom approach helps me become a better self-learner.

The inverted classroom approach does not encourage me to learn from my peers.*

The inverted classroom approach grows my life-long learning skills.

Figure 6: Perceived benefits of the inverted classroom pre-test results at University A and University B. Those questions asked in the negative (indicated by *) are shown with inverted responses in the graph, as if they were asked as positives.



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The inverted classroom approach does not encourage me to learn from my peers.*

The inverted classroom approach grows my life-long learning skills.

Figure 7: Perceived benefits of the inverted classroom post-test survey results at University A and University B. Those questions asked in the negative (indicated by *) are shown with inverted responses in the graph, as if they were asked as positives.

Discussion

While it was hoped that the students would see the benefits of the inverted classroom approach, they tended to express a less positive view of the technique after they had experienced it. There may be several reasons as to why. Other literature on the topic warns that students may be initially resistant to the new method,¹¹⁻¹² and that the videos must be linked to in-class exercises so they positively support each other and do not appear to be independent.¹² Further, there is not a “one size fits all” model for a flipped classroom,¹³ the content and the instructor’s approach are critical to the types of situations best suited for a flipped classroom.

At University A, the inverted classroom approach was instituted primarily to try to provide all students with a common level of instruction due to the variability present in the quality of the instruction between sections. While this was accomplished, and is supported by the increase in students’ agreement with question 8 on the survey, there was still much variability in what occurred within the classroom. On a separate survey conducted to evaluate the course, a number of students indicated that their instructor simply read through the slides used to create the videos instead of working through example problems with the students. These students expressed a great deal of frustration about this, which may have jaded them towards the whole inverted classroom approach. Unfortunately, due to the nature of how the data was collected, there is no way to explore whether the responses differed between those students whose instructor effectively employed the approach and those whose instructor did not. It was encouraging, however, that at University A, more students expressed a desire for a fully inverted classroom than at the beginning of the semester.

At University B, the inverted classroom approach was originally implemented because of decreased contact time in the classroom with the hope that the approach would allow more student-faculty interaction and active learning than might be available in a traditional classroom. Similar to University A, it would be interesting to see what impact the faculty interpretation and deployment of the classroom approach has on the responses given. It was discouraging to see that each benefit saw a negative shift in mean from the pre-test to the post-test and that the overall percentage increased for the traditional classroom preference from pre-test to post-test. Many of the students indicated dissatisfaction with the inverted classroom approach in that the learning became their responsibility rather than the instructors. Since one of the goals of the inverted classroom is to help students become better lifelong learners, this shift in responsibility is important.

University C was a bit different than the other two because the course was only partially inverted (the first half of the semester) and course content was informational for selecting an engineering major and did not contain computer programming content (which has been found to be very challenging for many students). The percentage of students interested in partially traditional and partially inverted classroom, regardless of prior knowledge or experience with an inverted classroom, increased indicating they liked the structure of the course they took (which had a 90% approval rating overall on course evaluations). The “final exam” for the course involved students meeting one on one with a faculty member to discuss their selection of an engineering major (88% of students enrolled in the course participated). From those sessions the student response to the course was overwhelmingly positive but the responses to the outside of class

videos they watched were mixed. Many students indicated it was a nice supplement to class activities but not critical to their understanding.

Conclusions

While student satisfaction with the approach is obviously not an indicator of learning and specific course content knowledge gained it is important to note that some of the benefits investigated in this study are skills that we do expect students to develop through their college experience. Mason, et. al reported that after students adapt to the new approach, they actually perform better on quiz / exam questions and also on open-ended design problems.¹¹ Developing the skills for handling open-ended problems, becoming a self-learner, and developing their lifelong learning skills is important to all engineers. Therefore, knowing whether or not the students think this approach helps in these key areas is important.

While it was interesting to see that some students became less satisfied with the inverted classroom, a majority of the students (80-90%) at all universities preferred an approach with at least a partial flip. Swartz et al.¹⁴ noted that it may not make sense to flip all areas of a course or all content and that it is not essential for a course to be 100% flipped. This is interesting to note and may lead faculty to consider looking at inverted classrooms and determining if a fully inverted classroom is necessary or if a partially inverted approach would be more effective.

One of the areas that may need improvement is the communication of the rationale behind the teaching approach. The large difference in how much students knew about the inverted classroom approach at the beginning of the semester, depending on which institution they attended, demonstrates that the universities vary in how they introduce the approach. Swartz et al.¹⁴ noted that getting buy in from the students is a suggestion when implementing the flipped classroom and that explaining the benefits is important because students may want to reject the approach since it is different from their prior classroom experiences. The first-year classroom provides a unique opportunity to combat this rejection to the inverted classroom approach. First-year students are experiencing many new things in their transition to college and thus adding the inverted classroom approach should result in less resistance from students than it would in a senior-level course where students have had years of traditional lecture-based classroom experiences in college. At University B, there has been an effort to add explanations of the inverted classroom to the students both at the beginning of the semester and as it is used. It is hoped that this additional reinforcement may improve student perceptions. Additionally, training sessions, either optional or mandatory, could be implemented at the beginning of the semester to teach students how to work with the inverted classroom. Training students how to better prepare for class may help them be more comfortable with the classroom approach. Additional research would be required to see if these strategies improve perceptions and also if the additional training improves understanding and course content knowledge. A longitudinal study could also examine if future exposure to the inverted classroom impacts perceptions.

Another area to be adjusted is more uniformity in how the approach is delivered by all the different course instructors. This is very difficult at Universities A and B where many faculty are delivering the content. Therefore, possible training could be implemented to explain to faculty about the approach, the reasoning behind it, and some best practices or tips and hints

from those who have taught with this approach before. Additionally, a future study may look at the link between the faculty implementation of the approach and the student experience. Also, faculty surveys could be implemented to see what feedback they have about the approach and how they see the benefits in their classroom.

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