Student performance in conventional and flipped classroom learning environments

This is the author's manuscript

Original Citation:

Availability:
This version is available http://hdl.handle.net/2318/1617506 since 2016-11-30T12:09:14Z

Published version:
DOI:10.13031/aea.32.11298

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(Article begins on next page)
This is the author's final version of the contribution published as:

Busato, P.; Berruto, R.; Zazueta, Fredo S; Silva-Lugo, J.. Student performance in conventional and flipped classroom learning environments. APPLIED ENGINEERING IN AGRICULTURE. 32 (5) pp: 509-518. DOI: 10.13031/aea.32.11298

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STUDENT PERFORMANCE IN CONVENTIONAL AND FLIPPED CLASSROOM LEARNING ENVIRONMENTS

Patrizia Busato, Remigio Berruto, Fedro S. Zazueta and José Silva-Lugo

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Abstract

Education and pedagogy are being transformed by developments in information technology and advances in learning theory that provide opportunities for improved outcomes in agricultural engineering education. The flipped classroom is a pedagogical model in which learning activities not requiring human interaction take place outside the classroom (enabled by technology) and learning activities requiring human interaction take place in the classroom (virtual or physical).

A pilot study compared the performance and preference by graduate students in a food chain logistics agricultural engineering course learning using a flipped classroom and a traditional face-to-face lecture modes of instruction. Two contiguous modules were developed in both modes of instruction. Students were divided into two groups, each group learning the course material using one module in each mode of instruction.

Students learning by the flipped classroom mode of instruction achieved significantly higher and more uniform test scores. Mean percentage scores for the flipped classroom ranged from 97.6% to 100% while mean scores under the conventional lecture ranged from 62% to 78.5%, with standard deviations ranging from 0 to 2.1 and 18.7 to 23.6, respectively. Also, a high level of significance (p<0.0001) was found showing a preference for the flipped classroom mode of instruction for the subject group. Students perceived they learn more, in less time, under the flipped classroom model.

The results of this study suggest that agricultural engineering education outcomes could be Improved by appropriate use of the flipped classroom model of teaching and learning.

Keywords: online learning, active learning, inverted class, student performance, student preference

Online learning has been recognized as strategically important to address global needs of education. As information technology (IT) made access to information ubiquitous, its importance to support and enable strategic actions at national
levels became evident. As early as 1998 UNESCO articulated a vision and framework for priority action for change and development in higher education (UNESCO, 1998). The US National Technology Plan (US Department of Education, 2010) presented a model for learning powered by technology based on the premise that advances in learning sciences and understanding how people learn, coupled with rapidly evolving developments in technology, create new challenges and opportunities for higher education. The European Commission (2010) articulated the importance of the innovation and modernization as fundamental to transform Europe into a competitive and inclusive economy. In a similar manner, other countries such as Italy (MIUR, 2013) and China (World Bank, 2007) have incorporated IT into their education strategy as well as programs enabled by IT to improve outcomes of research and education institutions.

The Italian Ministry of Education launched their 2007 National Plan for Digital Schools (Piano Nazionale Scuola Digitale). However, a review of the plan commissioned to the Organization for Economic Co-operation and Development (OECD) by the Ministry found that Italy lags behind other European countries in the adoption of IT in education (Avvisati et al., 2013). It is thus necessary that investments in IT in education not only improve learning outcomes, but also reduce the cost of instruction. Past experience demonstrated that this is achievable given the right investments and adoption of IT in education. (NCAT, 2014). Online delivery is now common place in strategic plans related to teaching and learning in higher education. This is often associated to improving learning outcomes, reducing the cost of instruction and innovation in teaching/learning (Williams et al., 2012).

It is clear that online learning works. Online learning is generally accepted as a direction in higher education institutions as an opportunity to modernize their work and create new channels that improve creative, entrepreneurial, and critical thinking skills. Also, online learning expands reach, thereby improving access and convenience. The issues that remain are related to finding the most effective and efficient ways to deliver this form of instruction (Bateman and Davies, 2014). For higher education in agricultural and biological engineering programs, challenges remain as a result of scarce budgetary resources for initial investments and the disruptive nature of the technology stemming from the cultural, historic and economic context.

Online delivery has enabled and made practical new pedagogical methods. One such method is the “flipped classroom”. The goals of this work were to: 1) Compare student performance in an agricultural engineering course delivered in a flipped classroom when compared to a conventional face-to-face teaching mode of instruction, and 2) to gain insight into student preference.

**The Flipped Classroom**

Advances in technology and learning theory and practice have created new directions and opportunities for pedagogy in engineering education. A pedagogy currently receiving much attention is the flipped classroom. The flipped classroom is
unique in its combination of active, problem-based learning constructivist ideas, and direct instruction methods based on behaviorist principles. This pedagogical approach is enabled by technological advances that permit the transmission and duplication of information at very low cost through various means, and the trend in education to make learning student-centered.

Consensus on a flipped classroom definition is lacking (Chen et al., 2014). A simple definition of inverted classroom is given by Lage (2000). Activities that traditionally take place in the classroom, take place outside the classroom in a flipped classroom, and vice versa. For the purpose of this work the flipped classroom is not in opposition of what is done in the traditional classroom, but in terms of human interaction. Thus, a flipped classroom is one in which learning activities not requiring human interaction take place outside the classroom (enabled by technology) and learning activities requiring human interaction take place in the classroom (virtual or physical). Fig. 1 illustrates this definition of the flipped classroom. Note that by this definition of a flipped classroom activities requiring human interaction may occur face-to-face or virtually, and in synchronous or asynchronous manners.

In this work, the focus of activities not requiring human interaction is for the student to understand and apply basic concepts related to the subject matter. These activities are in preparation for other activities requiring human interaction that focus on higher levels of learning in Bloom’s taxonomy (Krathwohl, 2002).

The main tools used that do not require human interaction were video, closed-problem solving, and quizzes. Early studies show that quality video lectures outperform traditional lectures (Cohen et al., 1981). Also, online homework is equally effective as paper and pencil (Bonham et al., 2003; Fynewever, 2008). These, coupled with quizzes for self-evaluation (Stallings and Tascoine, 1996) provide a solid base for the student to engage in activities requiring human interaction focused on higher level skills such as 1) communicating effectively, 2) identifying, formulating, and solving engineering problems, and 3) working collaboratively.

Specific activities requiring human interaction include the use of face-to-face and online discussion boards used to post and answer questions (students and faculty alike), and carefully crafted open-ended problems. Problems are selected to be tightly aligned with the learning objectives, ensuring that the topics are real and engaging to the students. This approach provides an opportunity to develop activities for active learning (Michael, 2006), cooperative learning (Foot and Howe, 1998), peer-assisted- learning (Topping and Ehly, 1998), and problem based learning (Barrows, 1996).

It is important to note that activities are not limited to those shown in Fig. 1. The number and type of activities can be diverse provided they focus on efficiently achieving a learning outcome and consider the learning style of the students (Zimmerman et al., 2006).

To assess the student performance and preferences of students a pilot comparing a flipped classroom and a conventional
face-to-face mode of instruction was designed. The course in this pilot, Food Chain Logistics, is an engineering course required for the graduate program in food science. The course is taught 80 hours per semester and has no prerequisites. Students in this course were in their second year of their M.S. program. All students in the course have a B.S. degree in food technology or agricultural science and engineering. Gender distribution was 5 females and 15 males ranging in age from 23 to 25 years old.

The objectives of the pilot were to:

1) Develop learning materials with identical objectives and content to be delivered by each mode of instruction.

2) Assess the performance of students under each mode of instruction by means of a high stakes test.

3) Gain insight into the student’s preferences for each mode of instruction using a survey.

4) To test the reliability and validity of the survey used to assess student preference.

5) To carry out the power analysis to estimate the sample size needed for conducting the study.

MATERIALS AND METHODS

EXPERIMENT DESIGN.

Common approaches to flipped classroom studies include the two simultaneous sections of a course being taught, one in each mode (A and B) to reduce variability, and each group exposed to both modes of instruction. Each module covered materials to be delivered over the equivalent of one week of instruction (3 lectures and a lab).

The experiment’s design was implemented in such a way that:

1) Students were assigned to each group at random, with students taking part of the course in each mode of instruction, thus avoiding the variability introduced by different groups of students.

2) The same instructor taught all modules against the same learning objectives, thus avoiding variability introduced by differences in learning materials, instructor, or teaching assistants.

3) Modules related to the same subject area were taught concurrently, thus avoiding variability introduced by teaching the modules (or course) in subsequent terms.

4) The group of students taking the course was not previously exposed to online learning, thus avoiding any previous bias related to technologies used in the delivery of the learning materials.

5) The design removed the variability introduced by participants because it was the same group subjected to two modes of instructions.
A problem that can arise in this experimental design is the possible dependence of Module 2 on Module 1. To eliminate this, the selection of the modules was made in such a way that module 2 does not require the skills acquired by the student in Module 1.

**Phases of the Experiment**

The experiment was carried out in the phases shown in Figure 2:

1) Development of course materials. Two contiguous modules of the course were prepared for conventional face-to-face and flipped classroom delivery as described below. Note that all learning materials for each mode of instruction had the same learning objectives and were based on the same content.

2) Delivery of Modules 1 and 2. A group of 20 students taking the course was divided at random into two groups, groups A and B. Each group was instructed in both conventional lecture and flipped classroom modes. Group A was subject to Module 1 in flipped form and Module 2 in conventional face-to-face delivery. Group B was subject to Module 1 in conventional face-to-face and Module 2 in flipped form. All modules were delivered by the same instructor. Also, it is important to note that students were required to complete the subject matter within a deadline.

3) Conduct preference survey. To gain some insights into the student’s perceptions about flipped and conventional methodologies a survey was conducted. All students (n=20), including those that opted not to take the high stakes assessment, filled the survey.

4) Test students for performance. Once students completed the survey they took a high-stakes test for the materials outlined in the learning objectives.

5) Analysis and evaluation. Finally, the results of the high stakes test and the survey were analyzed.

**DEVELOPMENT OF COURSE MODULES.**

The development of materials for the online component of the course was done in collaboration with the Center for Instructional technology and Training (CITT) at the University of Florida. The methodology used was that outlined by Sepulveda et al. (2006). The steps below were implemented by this method. The composition of the module development team is shown in Table 1.

**Knowledge domain definition.**

Two modules were selected for instruction that are of similar complexity, and that have the same number of lectures by traditional face-to-face delivery. The topical content is shown in Table 2.

**Specification of learning objectives.**

The main purpose of a learning objective is to clearly define the conduct or skill that the student must exhibit in relation to the knowledge domain and must include a clear statement of the expected observable behavior, the criterion by which
the learner performs and will be evaluated, and the conditions under which the learner is expected to perform. A clear
statement of the learning objectives for the course was the first and essential component of the production process from
which all other activities derived (Barros et al., 2008).

**Ontology of the learning objects.**

The ontology for the learning object used in this work extends the ontology presented by Sepulveda et al. (2006) to
differentiate between actions requiring and not requiring human interaction (Figure 3). The methodology for development
of the learning objects for this course is out of the scope of this paper and was done using a rapid prototyping approach.
This work was conducted with the assistance of an instructional designer and considering the flipped-classroom design
principles outlined by Kim et al. (2014). Figure 3 shows the relationship amongst the learning objectives, the self-
assessments, and compulsory learning materials. This methodical and consistent design process of the modules results in
an effective learning environment. It ensures that all components are harmonized with the desired outcome (learning
objective) and that no spurious materials that distract from the learning objective are included.

**Implementation of the learning objects.**

Once the knowledge domain and the learning objectives were clearly defined, self-assessment and evaluation assets
were produced. For the purpose of this work only a summative assessment was conducted. This was followed by creation
of the audiovisual material including MS PowerPoint presentations, videos, associated transcripts, problem examples,
closed problems, open-ended problems, and supplementary materials. It is important to note that a critical success
component for the flipped classroom is a very high quality video lecture with associated transcript of the video. None of
the video presentations or any of their components was improvised. A script was carefully developed for each video and
strictly adhered to ensuring that all content was directly related to the learning objectives. Videos were kept intentionally
short ranging in duration from 6 to 14 minutes. Video production took place in a fully equipped studio.

The toolset for the implementation of the modules was intentionally kept simple to ensure that access by students is
using readily available web technology and commonly used software. The software used during the trial is listed in Table
1.

Before the modules were released to the students taking the course they were carefully reviewed and tested by graduate
students to ensure that all components functioned as expected.

**DELIVERY OF MATERIALS TO STUDENTS**

The course was delivered using the Canvas® course management system. As a first step, students were required to
complete an introduction to the module that included a brief video tutorial on the use of the course management system to
ensure that lack of familiarity with the technology did not interfere with their learning.
Students were required to conduct a series of activities individually and socially. Individual online work consisted of watching videos of the basic concepts and theory, solution of exercise problems, and a quiz. For the component requiring human interaction of the flipped classroom, students were required to participate in an online discussion board, a question and answer session, and collaborate in open ended problem solving during the in-class activities.

For example, students viewed a video covering the principles related to this calculation (duration of 13:28 minutes) to attain the learning objective related to the computation of the Economic Order Quantity (EOQ). Thirteen slides were presented, and the transcript appeared at the bottom of each slide. Students were required to complete a four question quiz online after viewing this video. Optional material was provided consisting of an article related to economic order quantity calculation.

Use of the mathematical models was illustrated through a video of exercise related to EOQ calculation (6:24 minutes) and to Reorder Point calculation (2:31 minutes). In preparation for the discussion, students reviewed a video related to the Total Storage Cost calculation (11:34 minutes). This was followed by a discussion and critique on the rational and effective use of the mathematical models. This activity was conducted encouraging a high level of interaction among students, with the instructor playing a facilitator role, and was carried out using the discussion forum tool in the course management system. After the on-line discussion session, the “classroom activity” took place with students and faculty face-to-face. For this module, student teams were asked to collaborate and to formulate/present to their peers their approaches and solutions to an open-ended problem. This resulted in an engaging question and answer session followed by a thorough critical discussion of the learning materials.

**STUDENT PERFORMANCE ASSESSMENT**

Student performance was evaluated by means of a test (high stakes) on the materials for both groups of students. All students, regardless of the mode of instruction, took the same test at the same time. The grade on the test was taken as an indicator of student performance (command of the knowledge) and was recorded as a percentage, with 100% being the maximum score. Two students in group A and one student in Group B did not take the test. In addition, of the remaining students, two students in each group that took the test had not completed the modules. As a result the number of students taking the test for groups A and B were 8 and 9, respectively, and the number of students that took the test and completed the modules were 6 and 7, respectively.

**PREFERENCE SURVEY**

To assess student preferences, a research question “Do students prefer flipped classroom over traditional face-to-face modes of instruction?” was formulated. A survey was designed to reject or retain the null hypothesis: “There is no
difference between overall mean score for flipped-classroom and the overall mean score for traditional face-to-face mode of instruction.” The survey questions are shown in Fig. 4.

The survey focused on student perceptions related to understanding, quality of the materials and delivery, ability to use the acquired knowledge in open discussion, problem solving, convenience, and effort expended. A Likert Scale was used to quantify this question.

**Statistical Analysis**

For the performance assessment, a Chi-squared test applied to a 2x2 contingency table with the program R, compared student’s test grades in percentage for the topics taken in the flipped classroom versus the conventional face-to-face delivery. Because of the small sample size, the computation of the Chi-squared was based on the continuity of Yates (Agresti, 2007). The null hypothesis was \( Ho: \text{Flipped mean percentage Test Scores} - \text{Face-to-Face mean percentage test scores} = 0 \). For the preference survey, a median comparison per student was carried out by using the Wilcoxon Signed Rank Test because the majority of the variables were not normally distributed according to the Shapiro-Wilk test, and two modes of instruction were used for each student (dependent samples). The mean and median were calculated for each student for both modes of instruction. In a similar manner, a median comparison per survey question was carried out by using the Wilcoxon Signed Rank Test. The mean and median were calculated for each question for both modes of instruction. For the last two tests, the null hypothesis was: \( Ho: \text{Median Flipped} - \text{Median Face-to-Face} = 0 \). In addition, the overall median preference between the two modes of instruction was compared by using the Wilcoxon Signed Rank Test. The null hypothesis was \( Ho: \text{Overall Median Flipped} - \text{Overall Median Face-to-Face} = 0 \). The reliability and validity of the survey was tested by using Cronbach’s Alpha and the Spearman correlation between questions’ scores and total score, respectively. The Wilcoxon Signed Rank Tests, Cronbach’s Alpha, and Spearman correlation were carried out by using IBM SPSS Statistics v.22. We used two-tailed test and \( \alpha=0.05 \) for the proportion, median comparisons, and correlations.

After conducting this pilot study, a power analysis for the Paired-Difference T-Test was carried out by using IBM SPSS Power Sample III to determine the sample size needed for further studies. Two combined scenarios were created by plotting power vs sample size at three different values of: (a) mean difference (1.00, 1.60, and 2.33) and (b) \( \alpha \) (0.10, 0.05, and 0.01). The most extreme mean differences (1.00 and 2.33), a mean difference between these two (1.6), and its standard deviation (1.014) were chosen to do this analysis. The mean differences represented the effect size or the strength of the difference between the two instruction modes.
RESULTS AND DISCUSSION

STUDENT PERFORMANCE

The differences in performance of students learning the material in the flipped classroom versus the face-to-face mode are presented in Table 3. In each group, the mean percentage for test results for materials learned in the flipped classroom mode were significantly greater (P<0.0001) than the mean percentage for materials learned in the face-to-face course. Another very important outcome is the low variability of the scores related to the flipped classroom as shown in Table 4. The standard deviation from the mean is considerably smaller for the flipped classroom when compared to the face-to-face mode of delivery. This supports the notion that students in the flipped classroom mode perform better and more uniformly than students in the face-to-face mode. The low variability of student performance may be due to the accessibility of the material (anytime, anywhere, any device), the ability of students to proceed at their own pace, and the ability of students to view the materials as many times as necessary.

These results are consistent with the ones presented in the literature. Baepler et al. (2014) found that bio-engineering class students perform equally as well, and in some cases significantly better, and student perceptions were improved in the flipped classroom format. Tune et al. (2013) found that graduate student performance was improved by an average 12 points in multiple choice exams. Herreid and Schiller (2013) reported that student favorable perceptions to the flipped classroom mode.

STUDENT PREFERENCES

The student’s preference analysis by student is presented in Table 5. The comparison between flipped and face-to-face median preference score was significant (P<0.05) for all students with the exception of student 5. Thus, the flipped mode of instruction was preferred over the traditional one by almost all students. The perception that students reflected in the preference survey regarding a deeper understanding of the material when using the flipped classroom mode of instruction was corroborated by their performance during the test. However, given the context in which the research was carried out, it is important to note that these results should be taken as preliminary and that further study must be conducted to ensure the validity of this study on preference.

The results of the Wilcoxon Signed Rank Test for overall student’s preference are shown in Table 6. Also in this case, the P-value was significant (P<0.0001). Thus, the overall preference of the students is for the flipped classroom mode of instruction.

The results of the Wilcoxon Signed Rank Test to assess if the preference survey medians per question are significantly different, are shown in Table 7. The results indicate that the P-values are significant for all questions. Student median answers to the survey were significantly different and favorable to the flipped classroom. The mean responses per question
between flipped and face-to-face instruction modes in the student’s preference survey are presented in Fig. 5 and Table 7. The most favorable replies were related to: Ease of access to the material, anytime, anywhere (score 5.0), quality of online materials score (4.75), learning more and achieved a deeper understanding of the material (4.60), efficiently time investment (4.5). The medians associated with the mean scores were significantly different (P<0.05) from their counterparts in the face-to-face mode. Access to the materials anytime from anywhere, using any device, was stated as a very positive feature by individual comments (17 over 20 students posted the comment) and was confirmed by the highest score in the preference survey (5.0) in Fig. 5.

Open comments made by most students articulated that flexible access to the material in the flipped classroom allowed students to reduce travel time and expenses. This circumstance was convenient for working students. The smallest difference between flipped and traditional classroom was related to the ability to contribute to a discussion (4.37 vs. 3.47 for flipped and conventional, respectively), and the medians were significantly different (P<0.05). This result indicated that areas of improvements are still possible. From specific student comments related to this subject, it was clear that students needed more interaction than in the traditional classroom, possibly as a result of their deep involvement in the learning process. Mechanisms and tools for interaction appeared to be very important. Improving skills and familiarity with the use of the discussion tools of the online system may be helpful.

One very important general question that received a high score (4.55) was the willingness to take courses in the flipped classroom mode. This was interpreted as, if available, students would prefer to take courses in the flipped classroom over the conventional one. This should strongly encourage investments in this direction.

**RELIABILITY AND VALIDITY OF THE SURVEY**

Cronbach’s Alpha index was equal to 0.4928 and if we removed the second question, the index increased to 0.5555. These indexes were not acceptable and therefore the survey was not reliable. The validity test showed that it was not valid either because only four of the eight questions have significant correlations with the total score (Table 8). These results are due to the small number of questions. If you look at the questions in Figure 4, each question is simple, specific, balance, and neutral because they do not lead to a particular answer. Therefore, the wording of the questions is the correct one in order to produce consistence and accurate answers. Increasing the number of questions will make the survey reliable and valid.

**POWER ANALYSIS**

Figure 6 shows the relationship of power vs. sample size for two combined scenarios of changing α and the effect size. Looking at the three charts we can see two main results: (a) we need a larger sample size if alpha decreases (precision increases) and if the effect size is small, (b) five (effect size = 1.6; α = 0.10) and 18 (effect size = 1.0; α = 0.01) individuals
are the minimum and maximum sample size, respectively, that can be used to reject the Ho with a power of 80%.

CONCLUSIONS

The results of the student performance on a high stakes test and the preference survey show that:

1. On a high stakes test, students performed better and more uniformly when learning by the flipped classroom over the conventional face to face mode of instruction.

2. Students appeared to exhibit a strong preference for the flipped classroom over the conventional face to face mode of instruction.

3. Students involved in this study are willing to take courses in the flipped classroom mode.

As a general recommendation, Agricultural and Food Engineering programs that want to improve teaching and learning outcomes should consider investments in this area.

Of interest for future work is to determine if students not only prefer the flipped classroom mode of instruction and perform better in short term assessment, but to determine if this methodology improves long time retention of knowledge and critical thinking skills. In addition, improvements to the preference survey need to be made by increasing the number of questions and applying it to a larger and more diverse group of students.

It is important to note that because of the nature and size of the student group under which the study was conducted under, the results may not be generalizable to other student populations. However, this methodology may be useful to conduct similar studies.

ACKNOWLEDGEMENTS

The authors wish to thank those persons that made this study possible. To Ms. Angie Nicholson, Instructional Designer; Mr. Greg D’Angio, Video Specialist; Stephanie McClelland, Manager of Instructional Design Services; and, for their help in the development and production of the online resources. Finally, to the Office of Information Technology for providing the platform and necessary resources to deploy the course modules, and provide access to students to the University of Florida’s portal to follow the online components of the course.

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http://dx.doi.org/10.1002/9781118468135.ch17

http://ltcessays.files.wordpress.com/2012/08/teachingwithtechnologyv2a.pdf


Table 1: Module development team and toolset selected for implementation of the modules.

<table>
<thead>
<tr>
<th>Professional Type (number)</th>
<th>Average time invested per module¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor (1)</td>
<td>40</td>
</tr>
<tr>
<td>Instructional designer (1)</td>
<td>10</td>
</tr>
<tr>
<td>Videographer (2)</td>
<td>12</td>
</tr>
<tr>
<td>Graphics designer (1)</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tool</th>
<th>Name/Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Management System</td>
<td>Canvas (Instructure®)</td>
</tr>
<tr>
<td>Video Production</td>
<td>Mediasite (Sonicfoundry®)</td>
</tr>
<tr>
<td>Presentation</td>
<td>Powerpoint (Microsoft®)</td>
</tr>
<tr>
<td>Spreadsheet</td>
<td>Excel (Microsoft®)</td>
</tr>
<tr>
<td>Handouts and Transcriptions</td>
<td>Acrobat (Adobe®)</td>
</tr>
<tr>
<td>Grading</td>
<td>Speedgrader (Instructure®)</td>
</tr>
</tbody>
</table>

1. Each module covered materials to be delivered over the equivalent of one week of instruction (3 lectures and a lab).
Table 2. Knowledge domain for each module.

<table>
<thead>
<tr>
<th>Module 1</th>
<th>Module 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal order quantity for non-perishable products:</td>
<td>Service level and optimal order quantity for perishable produce:</td>
</tr>
<tr>
<td>• Types of stock</td>
<td>• Service Level Calculation</td>
</tr>
<tr>
<td>• Stock Cost</td>
<td>• Newsvendor Problem for Continuous Demand</td>
</tr>
<tr>
<td>• Economic Order Quantity (EOQ)</td>
<td>• Newsvendor Problem for Discrete Distribution Demand</td>
</tr>
<tr>
<td>• Reorder Point (ROP)</td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Proportion comparison between the two modes of instruction\(^1\)

<table>
<thead>
<tr>
<th>Groups: Modules</th>
<th>N</th>
<th>(\pi_1)</th>
<th>(\pi_2)</th>
<th>(X^2)</th>
<th>95% C.I.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A: Module 1 - Module 2</td>
<td>6</td>
<td>1.0000</td>
<td>0.7847</td>
<td>41.21</td>
<td>0.1497, 0.2809</td>
<td>1.37e(^{-10})</td>
</tr>
<tr>
<td>Group B: Module 1 - Module 2</td>
<td>7</td>
<td>0.6238</td>
<td>0.9762</td>
<td>79.30</td>
<td>-0.4258, -0.2789</td>
<td>2.20e(^{-16})</td>
</tr>
</tbody>
</table>

\(^1\) Only included are students that completed all modules.

\(N = \) number of students
\(\pi_1 = \) Module 1 mean proportion; \(\pi_2 = \) Module 2 mean proportion
\(X^2 = \) Chi-squared
95% C.I. = 95% Confidence Interval for \(\pi_1 - \pi_2\)

Table 4: Student Performance Mean Proportions and Standard Deviations

<table>
<thead>
<tr>
<th>N</th>
<th>Module 1</th>
<th>Module 2</th>
<th>Module 1</th>
<th>Module 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>6</td>
<td>100.00</td>
<td>78.47</td>
<td>0.00</td>
</tr>
<tr>
<td>Group B</td>
<td>7</td>
<td>62.38</td>
<td>97.62</td>
<td>18.66</td>
</tr>
</tbody>
</table>

\(^1\)Highlighted values correspond to the flipped classroom. Only included are students that completed all modules.
Table 5. Wilcoxon Signed Rank Test for the Student’s Preference Analysis

<table>
<thead>
<tr>
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<th>Flipped Mean (Median)</th>
<th>Traditional Mean (Median)</th>
<th>N</th>
<th>Standardized Test Statistic</th>
<th>P-Value</th>
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<tbody>
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<tr>
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<td>9</td>
<td>-2.72</td>
<td>0.007</td>
</tr>
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<td>-2.72</td>
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<td>0.006</td>
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<td>0.007</td>
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<tr>
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<td>3.00 (3.00)</td>
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<td>0.011</td>
</tr>
</tbody>
</table>

¹Note: Mean refers to the average value of the Likert scale.
Table 6: Overall preference tested with the Wilcoxon Signed Ranked Test.

<table>
<thead>
<tr>
<th>Flipped Mean (Median)</th>
<th>Traditional Mean (Median)</th>
<th>N</th>
<th>Standardized Test Statistic</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.51 (5.00)</td>
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<td>&lt; 0.001</td>
</tr>
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<td>Traditional Mean (Median)</td>
<td>N</td>
<td>Standardized Test Statistic</td>
</tr>
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<td>----------</td>
<td>-----------------------</td>
<td>---------------------------</td>
<td>---</td>
<td>----------------------------</td>
</tr>
<tr>
<td>1</td>
<td>4.63 (5.00)</td>
<td>2.95 (3.00)</td>
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<tr>
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<tr>
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<td>2.00 (2.00)</td>
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<td>4.63 (5.00)</td>
<td>2.68 (3.00)</td>
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<tr>
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<td>4.16 (4.00)</td>
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Table 8: Spearman correlation among questions and total score

<table>
<thead>
<tr>
<th>Question</th>
<th>Correlation</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
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<tbody>
<tr>
<td>Q1</td>
<td>Correlation</td>
<td>1</td>
<td>0.236</td>
<td>-0.242</td>
<td>0.15</td>
<td>-0.042</td>
<td>0.329</td>
<td>-0.267</td>
<td>0.178</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>0.317</td>
<td>0.304</td>
<td>0.529</td>
<td>0.862</td>
<td>0.156</td>
<td>0.255</td>
<td>0.454</td>
<td></td>
<td></td>
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<tr>
<td>Q2</td>
<td>Correlation</td>
<td>0.236</td>
<td>1</td>
<td>-0.091</td>
<td>0.079</td>
<td>-0.236</td>
<td>0.099</td>
<td>-0.465*</td>
<td>-0.022</td>
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</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.</td>
<td>0.317</td>
<td>0.702</td>
<td>0.74</td>
<td>0.317</td>
<td>0.677</td>
<td>0.039</td>
<td>0.926</td>
<td></td>
<td></td>
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<tr>
<td>Q3</td>
<td>Correlation</td>
<td>-0.242</td>
<td>-0.091</td>
<td>1</td>
<td>-0.07</td>
<td>.</td>
<td>0</td>
<td>0.221</td>
<td>0.366</td>
<td>0.39</td>
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<tr>
<td>Sig. (2-tailed)</td>
<td>0.304</td>
<td>0.702</td>
<td>0.771</td>
<td>.</td>
<td>1</td>
<td>0.349</td>
<td>0.113</td>
<td>0.09</td>
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<td>-0.07</td>
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<td>.</td>
<td>0.15</td>
<td>0.17</td>
<td>0.131</td>
<td>0.077</td>
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<tr>
<td>Sig. (2-tailed)</td>
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<td>0.74</td>
<td>0.771</td>
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<td>0.529</td>
<td>0.472</td>
<td>0.582</td>
<td>0.747</td>
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<tr>
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<tr>
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<td>-0.236</td>
<td>0</td>
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<td>.</td>
<td>1</td>
<td>0.132</td>
<td>0.123</td>
<td>0.178</td>
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<tr>
<td>Sig. (2-tailed)</td>
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<td>0.317</td>
<td>1</td>
<td>0.529</td>
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<td>.</td>
<td>0.58</td>
<td>0.605</td>
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<td>0.472</td>
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<tr>
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<td>0.747</td>
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<td>0.454</td>
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<td>0.061</td>
<td>.523*</td>
<td>0.409</td>
<td>.</td>
<td>0.27</td>
<td>.600**</td>
<td>.499*</td>
<td>.755**</td>
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<td>0.005</td>
<td>0.025</td>
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<tr>
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<td>20</td>
<td>20</td>
<td>20</td>
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</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

a Cannot be computed because at least one of the variables is constant.
## Flipped Classroom

<table>
<thead>
<tr>
<th>Does not Require Human Interaction</th>
<th>Requires Human Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Includes activities that can be conducted individually)</td>
<td>(Includes all activities conducted socially, face-to-face, online, synchronously or asynchronously)</td>
</tr>
</tbody>
</table>

*Learning Theory:* Behavioral
Skinner (1953), Reynolds (1975), Weiss (2014)

*Example primary activities:*
- Video Lectures
- Practice Problems
- Quizzes

*Learning Theory:* Constructivist

*Example primary activities:*
- Question/Answer
- Discussion
- Collaborative open-ended Problem Solving

---

Figure 1. Theoretical framework for the flipped classroom mode of instruction.
Figure 2. Phases of the study to compare student performance and preferences. During the first stage course objectives, learning and assessment materials were developed for both modes of instruction. Materials were then delivered to in both modes of instruction followed by a survey. All students were administered the same high stakes test. Finally, student performance and preferences were analyzed.
Figure 3. Learning objects ontology for a learning objective and associated materials.
Figure 4. Survey used to determine student preferences between flipped classroom and conventional face-to-face instruction.
Figure 5. Mean response per question between flipped and face-to-face instruction modes in the student’s preference survey presented in Fig. 4. Questions from the survey are abbreviated.
Figure 6: Power as a function of sample size for three effect sizes and values of $\alpha$. 