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# STUDENT PERFORMANCE IN CONVENTIONAL AND FLIPPED CLASSROOM LEARNING ENVIRONMENTS

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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

29 levels became evident. As early as 1998 UNESCO articulated a vision and framework for priority action for change and  
30 development in higher education (UNESCO, 1998). The US National Technology Plan (US Department of Education,  
31 2010) presented a model for learning powered by technology based on the premise that advances in learning sciences and  
32 understanding how people learn, coupled with rapidly evolving developments in technology, create new challenges and  
33 opportunities for higher education. The European Commission (2010) articulated the importance of the innovation and  
34 modernization as fundamental to transform Europe into a competitive and inclusive economy. In a similar manner, other  
35 countries such as Italy (MIUR, 2013) and China (World Bank, 2007) have incorporated IT into their education strategy as  
36 well as programs enabled by IT to improve outcomes of research and education institutions.

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

45 It is clear that online learning works. Online learning is generally accepted as a direction in higher education  
46 institutions as an opportunity to modernize their work and create new channels that improve creative, entrepreneurial, and  
47 critical thinking skills. Also, online learning expands reach, thereby improving access and convenience. The issues that  
48 remain are related to finding the most effective and efficient ways to deliver this form of instruction (Bateman and Davies,  
49 2014). For higher education in agricultural and biological engineering programs, challenges remain as a result of scarce  
50 budgetary resources for initial investments and the disruptive nature of the technology stemming from the cultural, historic  
51 and economic context.

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

## 56 **THE FLIPPED CLASSROOM**

57 Advances in technology and learning theory and practice have created new directions and opportunities for pedagogy in  
58 engineering education. A pedagogy currently receiving much attention is the flipped classroom. The flipped classroom is

59 unique in its combination of active, problem-based learning constructivist ideas, and direct instruction methods based on  
60 behaviorist principles. This pedagogical approach is enabled by technological advances that permit the transmission and  
61 duplication of information at very low cost through various means, and the trend in education to make learning student-  
62 centered.

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

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

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

80 Specific activities requiring human interaction include the use of face-to-face and online discussion boards used to post  
81 and answer questions (students and faculty alike), and carefully crafted open-ended problems. Problems are selected to be  
82 tightly aligned with the learning objectives, ensuring that the topics are real and engaging to the students. This approach  
83 provides an opportunity to develop activities for active learning (Michael, 2006), cooperative learning (Foot and Howe,  
84 1998), peer-assisted- learning (Topping and Ehly, 1998), and problem based learning (Barrows, 1996).

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

88 To assess the student performance and preferences of students a pilot comparing a flipped classroom and a conventional

89 face-to-face mode of instruction was designed. The course in this pilot, Food Chain Logistics, is an engineering course  
90 required for the graduate program in food science. The course is taught 80 hours per semester and has no prerequisites.  
91 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  
92 food technology or agricultural science and engineering. Gender distribution was 5 females and 15 males ranging in age  
93 from 23 to 25 years old.

94 The objectives of the pilot were to:

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

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

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

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

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

100

## 101 **MATERIALS AND METHODS**

### 102 **EXPERIMENT DESIGN.**

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

106

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

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

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

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

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

116 5) The design removed the variability introduced by participants because it was the same group subjected to two modes  
117 of instructions.

118 A problem that can arise in this experimental design is the possible dependence of Module 2 on Module 1. To  
119 eliminate this, the selection of the modules was made in such a way that module 2 does not require the skills acquired by  
120 the student in Module 1.

### 121 *Phases of the Experiment*

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

- 123 1) Development of course materials. Two contiguous modules of the course were prepared for conventional face-to-  
124 face and flipped classroom delivery as described below. Note that all learning materials for each mode of  
125 instruction had the same learning objectives and were based on the same content.
- 126 2) Delivery of Modules 1 and 2. A group of 20 students taking the course was divided at random into two groups,  
127 groups A and B. Each group was instructed in both conventional lecture and flipped classroom modes. Group A  
128 was subject to Module 1 in flipped form and Module 2 in conventional face-to-face delivery. Group B was subject  
129 to Module 1 in conventional face-to-face and Module 2 in flipped form. All modules were delivered by the same  
130 instructor. Also, it is important to note that students were required to complete the subject matter within a deadline.
- 131 3) Conduct preference survey. To gain some insights into the student's perceptions about flipped and conventional  
132 methodologies a survey was conducted. All students (n=20), including those that opted not to take the high stakes  
133 assessment, filled the survey.
- 134 4) Test students for performance. Once students completed the survey they took a high-stakes test for the materials  
135 outlined in the learning objectives.
- 136 5) Analysis and evaluation. Finally, the results of the high stakes test and the survey were analyzed.

### 137 **DEVELOPMENT OF COURSE MODULES.**

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

### 142 **Knowledge domain definition.**

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

### 145 **Specification of learning objectives.**

146 The main purpose of a learning objective is to clearly define the conduct or skill that the student must exhibit in relation  
147 to the knowledge domain and must include a clear statement of the expected observable behavior, the criterion by which

148 the learner performs and will be evaluated, and the conditions under which the learner is expected to perform. A clear  
149 statement of the learning objectives for the course was the first and essential component of the production process from  
150 which all other activities derived (Barros et al., 2008).

#### 151 **Ontology of the learning objects.**

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

#### 160 **Implementation of the learning objects.**

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

169 The toolset for the implementation of the modules was intentionally kept simple to ensure that access by students is  
170 using readily available web technology and commonly used software. The software used during the trial is listed in Table  
171 1.

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

#### 174 **DELIVERY OF MATERIALS TO STUDENTS**

175 The course was delivered using the Canvas<sup>®</sup> course management system. As a first step, students were required to  
176 complete an introduction to the module that included a brief video tutorial on the use of the course management system to  
177 ensure that lack of familiarity with the technology did not interfere with their learning.



178 Students were required to conduct a series of activities individually and socially. Individual online work consisted of  
179 watching videos of the basic concepts and theory, solution of exercise problems, and a quiz. For the component requiring  
180 human interaction of the flipped classroom, students were required to participate in an online discussion board, a question  
181 and answer session, and collaborate in open ended problem solving during the in-class activities.

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

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

#### 196 **STUDENT PERFORMANCE ASSESSMENT**

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

204

#### 205 **PREFERENCE SURVEY**

206 To assess student preferences, a research question “Do students prefer flipped classroom over traditional face-to-face  
207 modes of instruction?” was formulated. A survey was designed to reject or retain the null hypothesis: “There is no

208 difference between overall mean score for flipped-classroom and the overall mean score for traditional face-to-face mode  
209 of instruction.” The survey questions are shown in Fig. 4.

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

### 213 **STATISTICAL ANALYSIS**

214 For the performance assessment, a Chi-squared test applied to a 2x2 contingency table with the program R, compared  
215 student’s test grades in percentage for the topics taken in the flipped classroom versus the conventional face-to-face  
216 delivery. Because of the small sample size, the computation of the Chi-squared was based on the continuity of Yates  
217 (Agresti, 2007). The null hypothesis was  $H_0$ : Flipped mean percentage Test Scores – Face-to-Face mean percentage test  
218 scores = 0. For the preference survey, a median comparison per student was carried out by using the Wilcoxon Signed  
219 Rank Test because the majority of the variables were not normally distributed according to the Shapiro-Wilk test, and two  
220 modes of instruction were used for each student (dependent samples). The mean and median were calculated for each  
221 student for both modes of instruction. In a similar manner, a median comparison per survey question was carried out by  
222 using the Wilcoxon Signed Rank Test. The mean and median were calculated for each question for both modes of  
223 instruction. For the last two tests, the null hypothesis was:  $H_0$ : Median Flipped - Median Face-to-Face = 0. In addition, the  
224 overall median preference between the two modes of instruction was compared by using the Wilcoxon Signed Rank  
225 Test. The null hypothesis was  $H_0$ : Overall Median Flipped - Overall Median Face-to-Face = 0. The reliability and validity  
226 of the survey was tested by using Cronbach’s Alpha and the Spearman correlation between questions’ scores and total  
227 score, respectively. The Wilcoxon Signed Rank Tests, Cronbach’s Alpha, and Spearman correlation were carried out by  
228 using IBM SPSS Statistics v.22. We used two-tailed test and  $\alpha=0.05$  for the proportion, median comparisons, and  
229 correlations.

230 After conducting this pilot study, a power analysis for the Paired-Difference T-Test was carried out by using IBM SPSS  
231 Power Sample III to determine the sample size needed for further studies. Two combined scenarios were created by  
232 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,  
233 and 0.01). The most extreme mean differences (1.00 and 2.33), a mean difference between these two (1.6), and its  
234 standard deviation (1.014) were chosen to do this analysis. The mean differences represented the effect size or the strength  
235 of the difference between the two instruction modes.

## 236 **RESULTS RESULTS AND DISCUSSION**

### 237 **STUDENT PERFORMANCE**

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

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

### 252 **STUDENT PREFERENCES**

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

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

263 The results of the Wilcoxon Signed Rank Test to assess if the preference survey medians per question are significantly  
264 different, are shown in Table 7. The results indicate that the P-values are significant for all questions. Student median  
265 answers to the survey were significantly different and favorable to the flipped classroom. The mean responses per question

266 between flipped and face-to-face instruction modes in the student's preference survey are presented in Fig. 5 and Table 7.  
267 The most favorable replies were related to: Ease of access to the material, anytime, anywhere (score 5.0), quality of online  
268 materials score (4.75), learning more and achieved a deeper understanding of the material (4.60), efficiently time  
269 investment (4.5). The medians associated with the mean scores were significantly different ( $P < 0.05$ ) from their  
270 counterparts in the face-to-face mode. Access to the materials anytime from anywhere, using any device, was stated as a  
271 very positive feature by individual comments (17 over 20 students posted the comment) and was confirmed by the highest  
272 score in the preference survey (5.0) in Fig. 5.

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

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

#### 284 **RELIABILITY AND VALIDITY OF THE SURVEY**

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

#### 292 **POWER ANALYSIS**

293 Figure 6 shows the relationship of power vs. sample size for two combined scenarios of changing  $\alpha$  and the effect size.  
294 Looking at the three charts we can see two main results: (a) we need a larger sample size if alpha decreases (precision  
295 increases) and if the effect size is small, (b) five (effect size = 1.6;  $\alpha = 0.10$ ) and 18 (effect size = 1.0;  $\alpha = 0.01$ ) individuals

296 are the minimum and maximum sample size, respectively, that can be used to reject the  $H_0$  with a power of 80%.

297

## 298 **CONCLUSIONS**

299

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

- 301 1. On a high stakes test, students performed better and more uniformly when learning by the flipped classroom over  
302 the conventional face to face mode of instruction.
- 303 2. Students appeared to exhibit a strong preference for the flipped classroom over the conventional face to face  
304 mode of instruction.
- 305 3. Students involved in this study are willing to take courses in the flipped classroom mode.

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

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

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

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321 Florida's portal to follow the online components of the course.

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399 personality types and learning styles of engineering students, agricultural systems management students, and faculty in an Agricultural

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

Professional Type (number)	Average time invested per module <sup>1</sup>
Instructor (1)	40
Instructional designer (1)	10
Videographer (2)	12
Graphics designer (1)	4

Tool	Name/Provider
Course Management System	Canvas (Instructure®)
Video Production	Mediasite (Sonicfoundry®)
Presentation	Powerpoint (Microsoft®)
Spreadsheet	Excel (Microsoft®)
Handouts and Transcriptions	Acrobat (Adobe®)
Grading	Speedgrader (Instructure®)

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1. Each module covered materials to be delivered over the equivalent of one week of instruction (3 lectures and a lab).

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Table 2. Knowledge domain for each module.

Module 1	Module 2
Optimal order quantity for non-perishable products: <ul style="list-style-type: none"><li>• Types of stock</li><li>• Stock Cost</li><li>• Economic Order Quantity (EOQ)</li><li>• Reorder Point (ROP)</li></ul>	Service level and optimal order quantity for perishable produce: <ul style="list-style-type: none"><li>• Service Level Calculation</li><li>• Newsvendor Problem for Continuous Demand</li><li>• Newsvendor Problem for Discrete Distribution Demand</li></ul>

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411 Table 3. Proportion comparison between the two modes of instruction<sup>1</sup>

<b>Groups: Modules</b>	<b>N</b>	<b><math>\pi_1</math></b>	<b><math>\pi_2</math></b>	<b><math>X^2</math></b>	<b>95% C.I.</b>	<b>P-value</b>
Group A: Module 1- Module 2	6	1.0000	0.7847	41.21	0.1497, 0.2809	1.37e <sup>-10</sup>
Group B: Module 1- Module 2	7	0.6238	0.9762	79.30	-0.4258, -0.2789	2.20e <sup>-16</sup>

412 <sup>1</sup>Only included are students that completed all modules.

413 N = number of students

414  $\pi_1$  = Module 1 mean proportion;  $\pi_2$  = Module 2 mean proportion

415  $X^2$  = Chi-squared

416 95% C.I. = 95% Confidence Interval for  $\pi_1$ -  $\pi_2$

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419 Table 4: Student Performance Mean Proportions and Standard Deviations

	<b>N</b>	<b>Mean</b>		<b>Standard Deviation</b>	
		<b>Module 1</b>	<b>Module 2</b>	<b>Module 1</b>	<b>Module 2</b>
Group A	6	100.00	78.47	0.00	23.62
Group B	7	62.38	97.62	18.66	2.06

421 <sup>1</sup>Highlighted values correspond to the flipped classroom. Only included are students that completed all modules.

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Table 5. Wilcoxon Signed Rank Test for the Student's Preference Analysis<sup>1</sup>

<b>Student</b>	<b>Flipped Mean (Median)</b>	<b>Traditional Mean (Median)</b>	<b>N</b>	<b>Standardized Test Statistic</b>	<b>P-Value</b>
1	4.22 (4.00)	2.67 (3.00)	9	-2.57	0.010
2	4.44 (5.00)	2.56 (2.00)	9	-2.54	0.011
3	4.11 (4.00)	3.11 (3.00)	9	-2.25	0.024
4	5.00 (3.00)	2.78 (4.00)	9	-2.69	0.007
5	3.89 (5.00)	2.89 (3.00)	9	-1.81	0.071
6	4.44 (5.00)	3.00 (3.00)	9	-2.11	0.035
7	4.67 (5.00)	3.11 (3.00)	9	-2.46	0.014
8	4.56 (5.00)	2.44 (2.00)	9	-2.72	0.007
9	4.67 (5.00)	2.56 (3.00)	9	-2.70	0.007
10	4.33 (4.00)	3.22 (3.00)	9	-2.43	0.015
11	4.78 (5.00)	2.44 (3.00)	9	-2.75	0.006
12	4.56 (5.00)	2.89 (3.00)	9	-2.39	0.017
13	4.56 (5.00)	2.56 (3.00)	9	-2.69	0.007
14	4.78 (5.00)	3.00 (3.00)	9	-2.72	0.007
15	4.56 (5.00)	2.78 (3.00)	9	-2.38	0.017
16	4.78 (5.00)	2.78 (3.00)	9	-2.57	0.010
17	4.44 (4.00)	2.67 (3.00)	9	-2.72	0.006
18	4.56 (5.00)	2.56 (3.00)	9	-2.70	0.007
19	4.44 (4.00)	2.56 (3.00)	9	-2.70	0.007
20	4.44 (5.00)	3.00 (3.00)	9	-2.53	0.011

<sup>1</sup>Note: Mean refers to the average value of the Likert scale.

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Table 6: Overall preference tested with the Wilcoxon Signed Ranked Test.

<b>Flipped</b>	<b>Traditional</b>	<b>N</b>	<b>Standardized</b>	<b>P-Value</b>
<b>Mean (Median)</b>	<b>Mean (Median)</b>		<b>Test Statistic</b>	
4.51 (5.00)	2.78 (3.00)	180	-10.97	< 0.001

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Table 7: Wilcoxon Signed Rank Test per Question

<b>Question</b>	<b>Flipped Mean (Median)</b>	<b>Traditional Mean (Median)</b>	<b>N</b>	<b>Standardized Test Statistic</b>	<b>P-Value</b>
1	4.63 (5.00)	2.95 (3.00)	20	-3.80	< 0.001
2	4.79 (5.00)	3.00 (3.00)	20	-4.06	< 0.001
3	4.37 (5.00)	3.47 (3.00)	20	-3.29	0.001
4	4.47 (4.50)	2.79 (3.00)	20	-3.90	< 0.001
5	5.00 (5.00)	2.00 (2.00)	20	-3.99	< 0.001
6	4.63 (5.00)	2.68 (3.00)	20	-3.99	< 0.001
7	4.16 (4.00)	2.79 (3.00)	20	-3.60	< 0.001
8	4.53 (5.00)	2.11 (2.00)	20	-3.98	< 0.001
9	4.16 (4.00)	3.26 (3.00)	20	-2.59	0.010

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Table 8: Spearman correlation among questions and total score

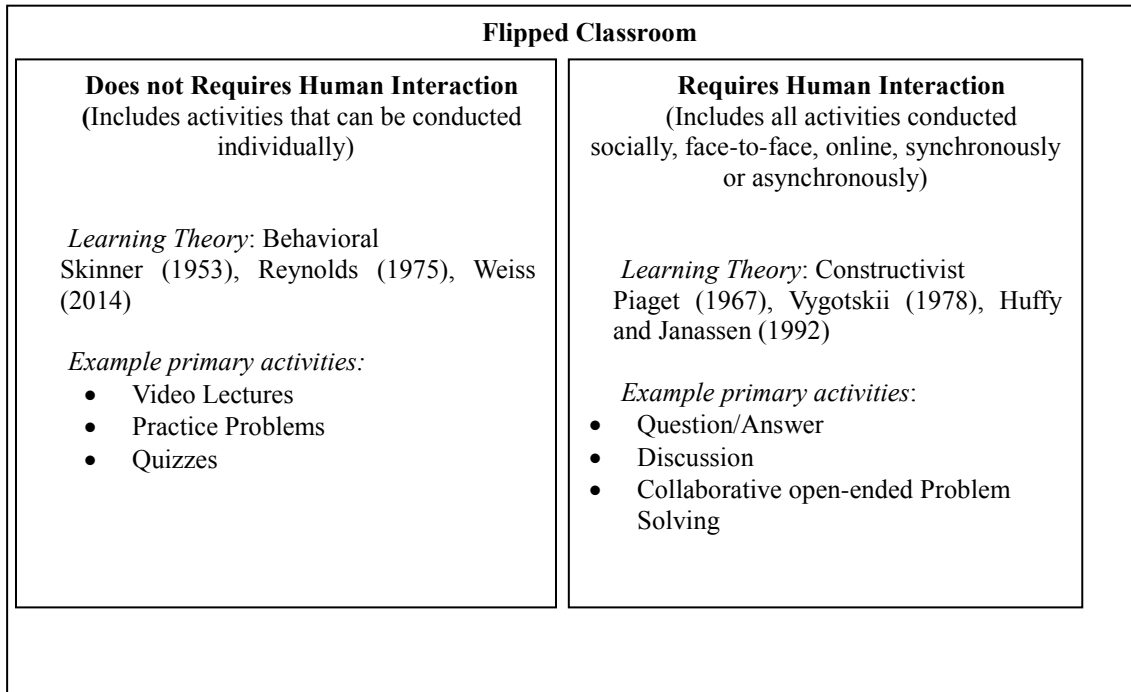
Question	Correlation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
<b>Q1</b>	Correlation	1	0.236	-0.242	0.15	.	-0.042	0.329	-0.267	0.178
	Sig. (2-tailed)	.	0.317	0.304	0.529	.	0.862	0.156	0.255	0.454
<b>Q2</b>	Correlation	0.236	1	-0.091	0.079	.	-0.236	0.099	-.465*	-0.022
	Sig. (2-tailed)	0.317	.	0.702	0.74	.	0.317	0.677	0.039	0.926
<b>Q3</b>	Correlation	-0.242	-0.091	1	-0.07	.	0	0.221	0.366	0.39
	Sig. (2-tailed)	0.304	0.702	.	0.771	.	1	0.349	0.113	0.09
<b>Q4</b>	Correlation	0.15	0.079	-0.07	1	.	0.15	0.17	0.131	0.077
	Sig. (2-tailed)	0.529	0.74	0.771	.	.	0.529	0.472	0.582	0.747
<b>Q5</b>	Correlation	.	.	.	.	.	.	.	.	.
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.
<b>Q6</b>	Correlation	-0.042	-0.236	0	0.15	.	1	0.132	0.123	0.178
	Sig. (2-tailed)	0.862	0.317	1	0.529	.	.	0.58	0.605	0.454
<b>Q7</b>	Correlation	0.329	0.099	0.221	0.17	.	0.132	1	0.153	0.372
	Sig. (2-tailed)	0.156	0.677	0.349	0.472	.	0.58	.	0.521	0.106
<b>Q8</b>	Correlation	-0.267	-.465*	0.366	0.131	.	0.123	0.153	1	0.335
	Sig. (2-tailed)	0.255	0.039	0.113	0.582	.	0.605	0.521	.	0.149
<b>Q9</b>	Correlation	0.178	-0.022	0.39	0.077	.	0.178	0.372	0.335	1
	Sig. (2-tailed)	0.454	0.926	0.09	0.747	.	0.454	0.106	0.149	.
<b>Total</b>	Correlation	0.216	0.061	.523*	0.409	.	0.27	.600**	.499*	.755**
	Sig. (2-tailed)	0.36	0.798	0.018	0.073	.	0.249	0.005	0.025	0
	N	20	20	20	20	20	20	20	20	20

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

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

436 a Cannot be computed because at least one of the variables is constant.



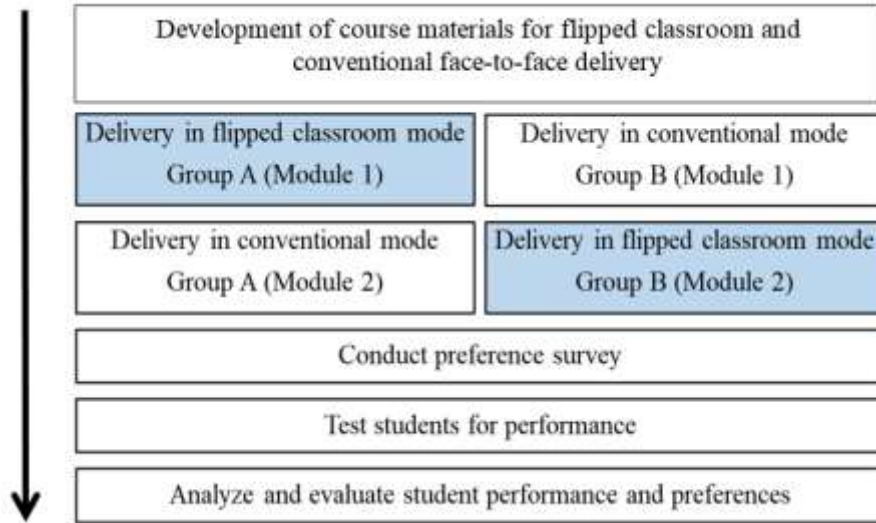


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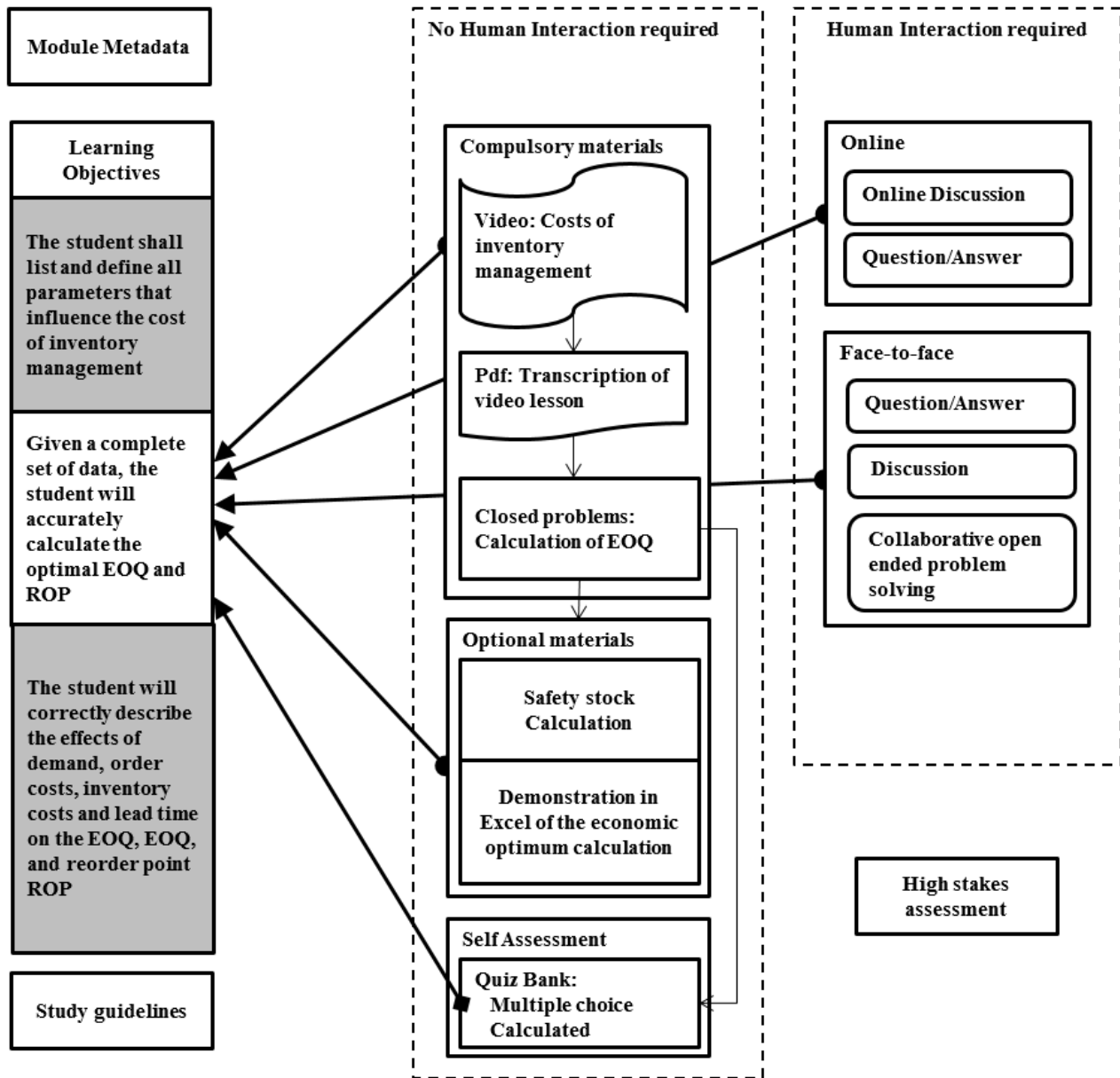
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Figure 1. Theoretical framework for the flipped classroom mode of instruction.



441

442 Figure 2. Phases of the study to compare student performance and preferences. During the first stage course objectives,  
443 learning and assessment materials were developed for both modes of instruction. Materials were then delivered to in both  
444 modes of instruction followed by a survey. All students were administered the same high stakes test. Finally, student  
445 performance and preferences were analyzed.



446

447 Figure 3. Learning objects ontology for a learning objective and associated materials.

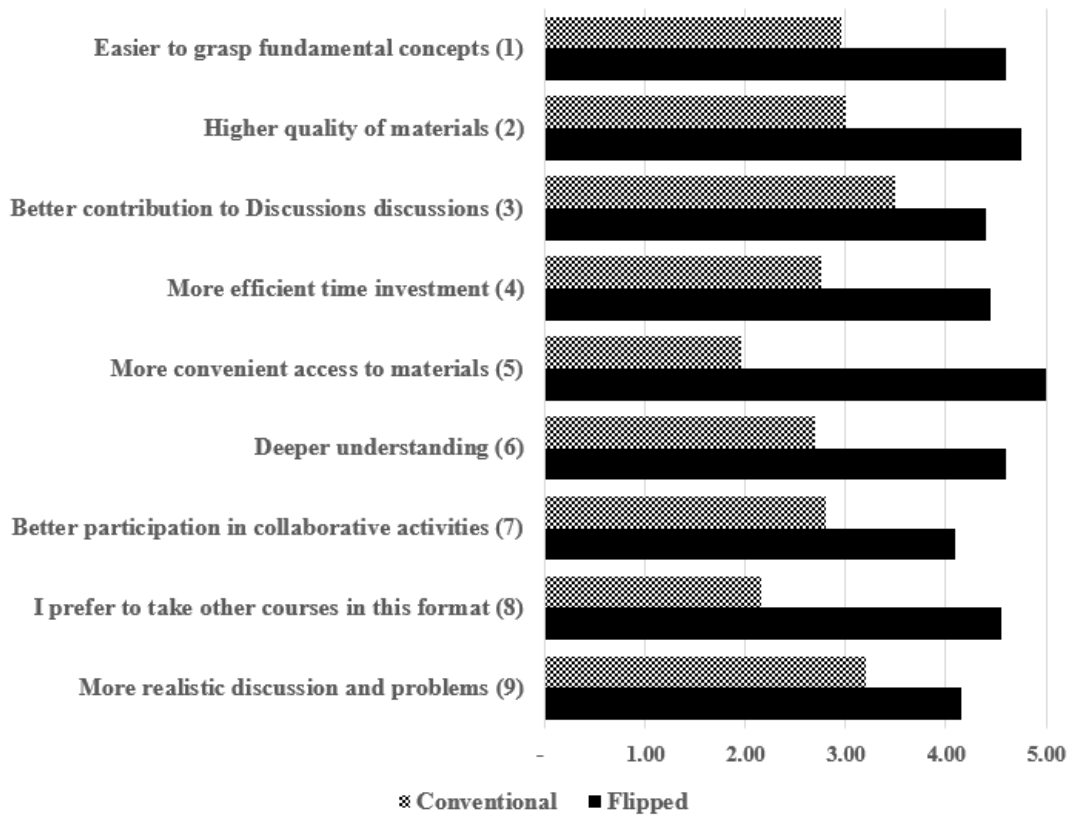
		Flipped Classroom				Face to Face					
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	It was easier for me to grasp the fundamental concepts related to food chain logistics										
2	The quality of the materials and methods used for delivery was high and more engaging										
3	I was able to better participate and contribute to the discussions										
4	The time I invested in studying was more efficiently used										
5	Access to materials anytime and from any location was more convenient for me										
6	I learned more and achieved a deeper understanding of the course materials										
7	I was able to better participate in the collaborative solution of open-ended problems										
8	I prefer to take other courses in this format										
9	The discussions and problems solved were of a higher and more realistic level										

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Figure 4. Survey used to determine student preferences between flipped classroom and conventional face-to-face instruction.

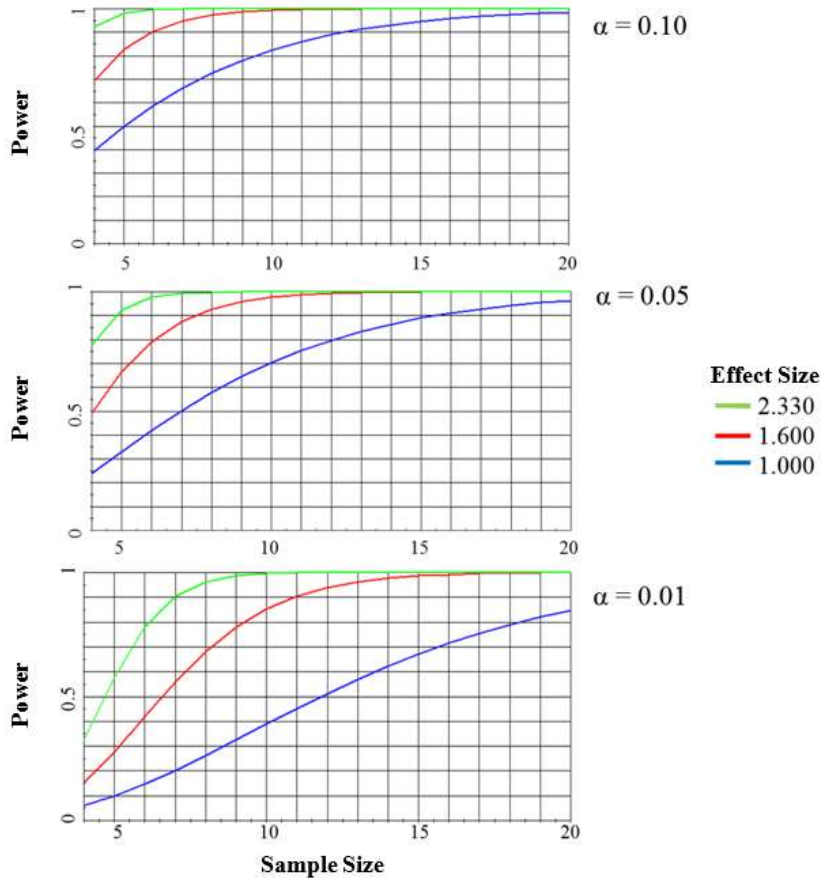


452

453     Figure 5. Mean response per question between flipped and face-to-face instruction modes in the student's preference

454 survey presented in Fig. 4. Questions from the survey are abbreviated.

455



457  
458 Figure 6: Power as a function of sample size for three effect sizes and values of  $\alpha$ .  
459  
460