Student performance in conventional and flipped classroom learning environments

(Article begins on next page)

07 January 2025

STUDENT PERFORMANCE IN CONVENTIONAL AND FLIPPED CLASSROOM LEARNING ENVIRONMENTS

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

The authors are **Patrizia Busato**, ASABE Member, Research Fellow, DISAFA, University of Turin, **Remigio Berruto**, ASABE Member and Associate Professor, DISAFA, University of Turin, **Fedro S. Zazueta**, ASABE Fellow, Associate CIO and Professor, University of Florida, and **Jose Silva Lugo**, Research Associate, University of Florida. **Corresponding author**: Fedro S. Zazueta, Tigert Hall, University of Florida, Gainesville, FL 32611. Email: fsz@ufl.edu.

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

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 is 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

MATERIALS AND METHODS

101

EXPERIMENT DESIGN.

102

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

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.

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 Ho: 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: Ho: 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 Ho: 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) α (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.

8

RESULTS 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

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 α 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; α = 0.10) and 18 (effect size = 1.0; α = 0.01) individuals

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

297

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.

REFERENCES

323

324   Avvisati, F., Hennessy, S., Kozma, R. B., and Vincent-Lancrin, S. (2013). Review of the Italian Strategy for Digital Schools. OECD

325   Education working papers, No. 90. Retrieved Jan 6, 2015, from

326   http://www.oecd.org/edu/ceri/Innovation%20Strategy%20Working%20Paper%2090.pdf

327   Baepler, P., Walker, J. D., and Driessen, M. (2014). It's not about seat time: Blending, flipping, and efficiency in active learning classrooms.

328   Computers and Education 78, 227-236.

329   Barros, G. C., Sepulveda, E. S. B., Williams, R. J., Beck, H., & Zazueta, F. S. (2008). A wizard for the creation of ontology-based learning

330   objects. Paper No. FL08-12. Paper presented at the ASABE Section Meeting Presentation.

331   Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. p. 3–12 In New Directions for Teaching and

332   Learning.

333   Bateman, J., and Davies, D. (2014). The challenge of disruptive innovation in learning technology. Medical Education, 48(3): 227-228.

334   Bonham, S. W., Deardorff, D. L., and Beichner, R. J. (2003). Comparison of Student Performance Using Web and Paper-Based Homework

335   in College-Level Physics. Journal of Research in Science and Teaching, 40(10): 1050-1071.

336   Chen, Y., Wang, Y., Kinshuk, and Chen, N.-S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? Computers &

337   Education, 79(0): 16-27.

338   Center for Instructional Technology and Training CITT. (2014). Faculty Institute. Retrieved Oct 12 , 2014, from:

339   http://teach.ufl.edu/development/faculty-institute/

340   Cohen, P. A., Ebeling, B. J., and Kulik, J. A. (1981). A meta-analysis of outcome studies of visual-based instruction. Educational

341   Communication and Technology Journal, 29(1): 26-36.

342   European Comission. (2010). Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth. Available at:

343   http://www.eea.europa.eu/policy-documents/com-2010-2020-europe-2020 [Accessed Dec. 20, 2014]

344   Foot, H., and Howe, C. (1998). The psychoeducational basis of peer-assisted learning. S. E. Keith Topping (Ed.), Peer-assisted Learning:

345   Lawrence Erlbaum Associates.

346   Fynewever, H. (2008). A comparison of the effectiveness of web-based and paper-based homework for general chemistry. The Chemical

347   Educator, 13: 264–269.

348   Herreid, C. F., and Schiller, N. A. (2013). Case Studies and the Flipped Classroom. Journal of College Science Teaching, 42(5):63-67.

349   Huffy, T. H., and Janassen, D. H. (1992). Constructivism and the technology of instruction: a conversation. Hillsdale, New Jersey, Lawrence

350   Erlbaum Associates, Inc.

351   Kim, M. K., Kim, S. M., Khera, O., and Getman, J. (2014). The experience of three flipped classrooms in an urban university: An

352   exploration of design principles. The Internet and Higher Education 22(0), 37-50.

353   Krathwohl, D. R. (2002). A revision of bloom's taxonomy: An overview. Theory into Practice 41(4), 212-218.

354   Lage, M. J., Platt, G. J., and Treglia, M. (2000). Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment. The

355   Journal of Economic Education, 31(1), 30-43.

356   Michael, J. (2006). Where is the evidence that active learning works? Advances in Physiology Education 30(4), 159-167.

357 MIUR (Producer). (2013). Piano nazionale scuola digitale (PNSD). Retrieved February 15 from

358   http://www.istruzione.it/allegati/Avviso_n.2945_25-11-2013_DGSSSI.pdf

359 NCAT. (2014). A summary of NCAT Program Outcomes. 2014). Retrieved October 10, 2014, from

360   http://thencat.org/Program_Outcomes_Summary.html

361 Ott, R. L. and M. T. Longnecker. 2010. Introduction to Statistical Methods and Data Analysis. 6th edition. Duxbury Press, Belmont,

362   California

363 Piaget, J. (1967). Six psychological studies. New York, Random House.

364 Reynolds, G. S. (1975). A primer of operant conditioning. Glenview, Ill., Scott, Foresman.

365 Sepulveda, E. S. B., Zazueta, F. S., Bucklin, R., and Hoces, E. A. H. (2006). Rapid prototyping of learning objects for agricultural and

366   biological engineering education. Applied Engineering in Agriculture 22(3), 461-475.

367 Skinner, B. F. 1953. Science and human behavior. New York, Macmillan.

368 Stallings, V., and Tascoine, C. (1996). Student Self-Assessment and Self-Evaluation. The Mathematics Teacher 89(7), 548-554.

369 Topping, K. J., and Ehly, S. W. (1998). Peer-assisted learning. Mahwah, N.J., L. Erlbaum Associates.

370 Tune, J. D., Sturek, M., and Basile, D. P. (2013). Flipped classroom model improves graduate student performance in cardiovascular,

371   respiratory, and renal physiology. American Journal of Physiology - Advances in Physiology Education, 37(4), 316-320.

372 UNESCO. (1998). World Declaration on Higher Education for the Twenty First Century: Vision and action and Framework for Priority

373   action for Change and Development in Higher Education.   Retrieved Dec 20, 2014, from

374   http://www.unesco.org/education/educprog/wche/declaration_eng.htm#world declaration

375 US Department of Education. (2010). Transforming American Education: Learning Powered by Technology. National Education

376   Technology Plan 2010.   Retrieved January 2nd, 2015, from http://tech.ed.gov/wp-content/uploads/2013/10/netp2010.pdf

377 Vygotskii, L. S., & Cole, M. (1978). Mind in society : The development of higher psychological processes. Cambridge: Harvard University

378   Press.

379 Weiss, S. J. (2014). Instrumental and Classical Conditioning: ahe Wiley Blackwell Handbook of Operant and Classical Conditioning (pp.

380   417-451). Retrieved from http://dx.doi.org/10.1002/9781118468135.ch17

381 Williams, R. J., Hartman, J. C., Zazueta, F. S., & Smith, J. (2012). Development for Student Success: An undergraduate Online Course in

382   Engineering. In G. C. Clark & S. A. Clouser (Eds.), Teaching with Technology, Volume 2: The Stories Continue (Vol. 2, pp. 101-106):

383   Learning Technology Consortium. Retrieved from http://ltcessays.files.wordpress.com/2012/08/teachingwithtechnologyv2a.pdf.

384 World Bank. (2007). China and the World Bank : a partnership for innovation.   Retrieved January 2nd, 2015, from

385   http://documents.worldbank.org/curated/en/2007/01/9739957/china-world-bank-partnership-innovation

386 Zimmerman, A. P., Johnson, R. G., Hoover, T. S., Hilton, J. W., Heinemann, P. H., & Buckmaster, D. R. (2006). Comparison of personality

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

388   Biological Engineering Department. Transactions of the ASABE, 49(1), 311-317.

389 Vygotskii, L. S., and Cole, M. (1978). Mind in Society: The development of higher psychological processes. Cambridge, Harvard

390   University Press.

391   Weiss, S. J. (2014). Instrumental and Classical Conditioning. John Wiley & Sons, Ltd. Retreived January 18 from:

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

393   Williams, R. J., Hartman, J. C., Zazueta, F. S., and Smith, J. (2012). Development for Student Success: An undergraduate Online Course in

394   Engineering. In: Vol. 2. G. C. Clark & S. A. Clouser (Eds.), Teaching with Technology, Volume 2: The Stories Continue. (pp. 101-106).

395   Retrieved August 14, 2014, from : http://ltcessays.files.wordpress.com/2012/08/teachingwithtechnologyv2a.pdf

396   World Bank. (2007). China and the World Bank : a partnership for innovation. Retrieved January 2nd, 2015.

397   http://documents.worldbank.org/curated/en/2007/01/9739957/china-world-bank-partnership-innovation

398   Zimmerman, A. P., Johnson, R. G., Hoover, T. S., Hilton, J. W., Heinemann, P. H., and Buckmaster, D. R. (2006). Comparison of

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

400   and Biological Engineering Department. Transactions of the ASABE, 49(1): 311-317.

401

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

Professional Type (number)	Average time invested per module[1]
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®)

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

406

407

Table 2. Knowledge domain for each module.

Module 1	Module 2
Optimal order quantity for non-perishable products: • Types of stock • Stock Cost • Economic Order Quantity (EOQ) • Reorder Point (ROP)	Service level and optimal order quantity for perishable produce: • Service Level Calculation • Newsvendor Problem for Continuous Demand • Newsvendor Problem for Discrete Distribution Demand

408

409

410

Table 3. Proportion comparison between the two modes of instruction[1]

Groups: Modules	N	$\pi 1$	$\pi 2$	X^2	95% C.I.	P-value
Group A: Module 1- Module 2	6	1.0000	0.7847	41.21	0.1497, 0.2809	$1.37e^{-10}$
Group B: Module 1- Module 2	7	0.6238	0.9762	79.30	-0.4258, -0.2789	$2.20e^{-16}$

412   [1] 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 $\pi 1$- $\pi 2$

417

418

419

Table 4: Student Performance Mean Proportions and Standard Deviations

420

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

421   [1] Highlighted values correspond to the flipped classroom. Only included are students that completed all modules.

422

423

Table 5. Wilcoxon Signed Rank Test for the Student's Preference Analysis[1]

Student	Flipped Mean (Median)	Traditional Mean (Median)	N	Standardized Test Statistic	P-Value
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

[1]Note: Mean refers to the average value of the Likert scale.

424

425

426

427

Table 6: Overall preference tested with the Wilcoxon Signed Ranked Test.				
Flipped Mean (Median)	**Traditional Mean (Median)**	**N**	**Standardized Test Statistic**	**P-Value**
4.51 (5.00)	2.78 (3.00)	180	-10.97	< 0.001

428

429

430

431

Table 7: Wilcoxon Signed Rank Test per Question

Question	Flipped Mean (Median)	Traditional Mean (Median)	N	Standardized Test Statistic	P-Value
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

432

433   Table 8: Spearman correlation among questions and total score

Question	Correlation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1	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
Q2	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
Q3	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
Q4	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
Q5	Correlation	.	.	.	.	.	.	.	.	.
	Sig. (2-tailed)	.	.	.	.	.	.	.	.	.
Q6	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
Q7	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
Q8	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
Q9	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	.
Total	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.
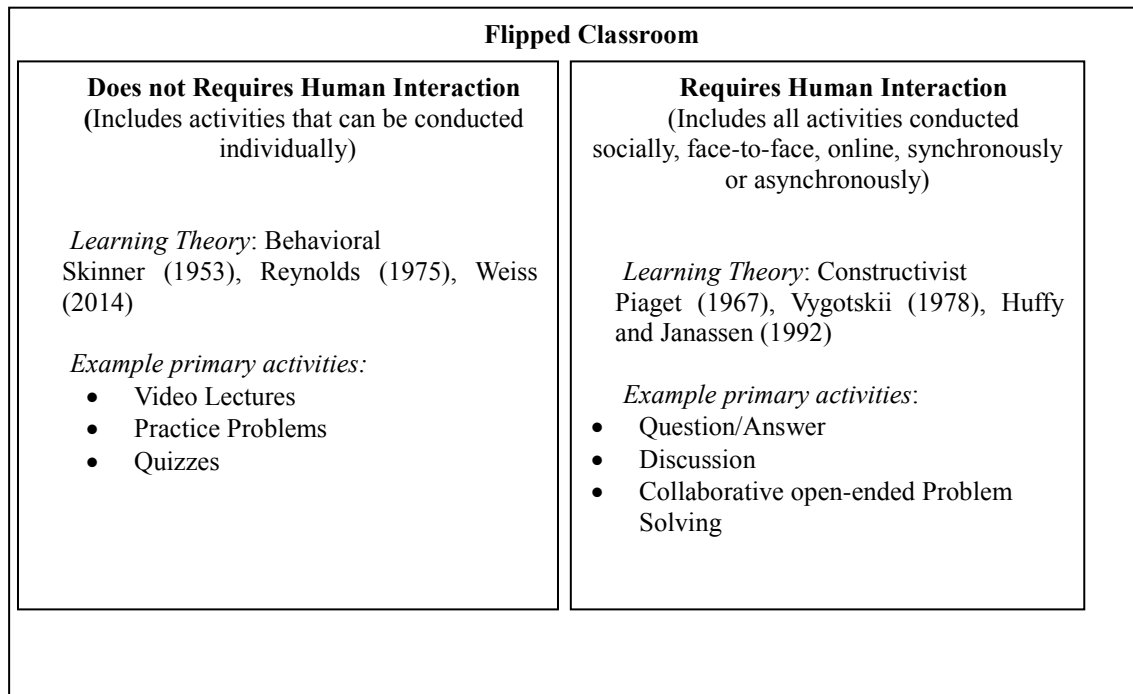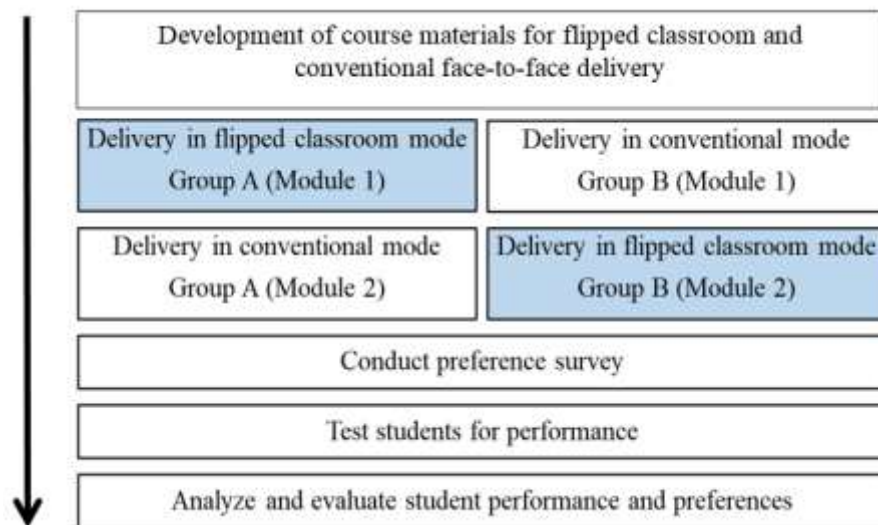
Flipped Classroom	
Does not Requires Human Interaction (Includes activities that can be conducted individually) *Learning Theory*: Behavioral Skinner (1953), Reynolds (1975), Weiss (2014) *Example primary activities:* • Video Lectures • Practice Problems • Quizzes	**Requires Human Interaction** (Includes all activities conducted socially, face-to-face, online, synchronously or asynchronously) *Learning Theory*: Constructivist Piaget (1967), Vygotskii (1978), Huffy and Janassen (1992) *Example primary activities*: • Question/Answer • Discussion • Collaborative open-ended Problem Solving

437

438

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

440

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.
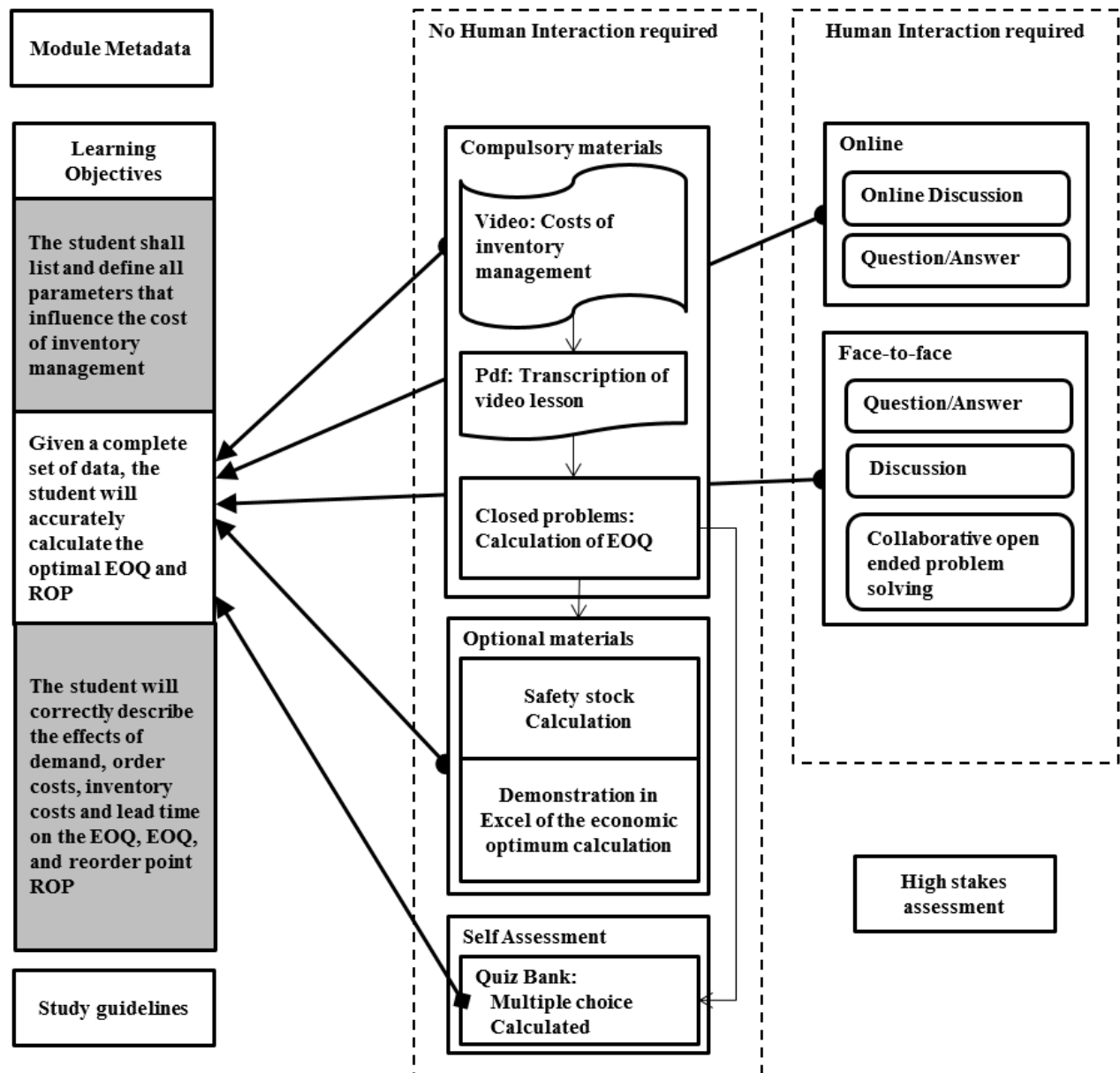
446

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

448

		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										

449

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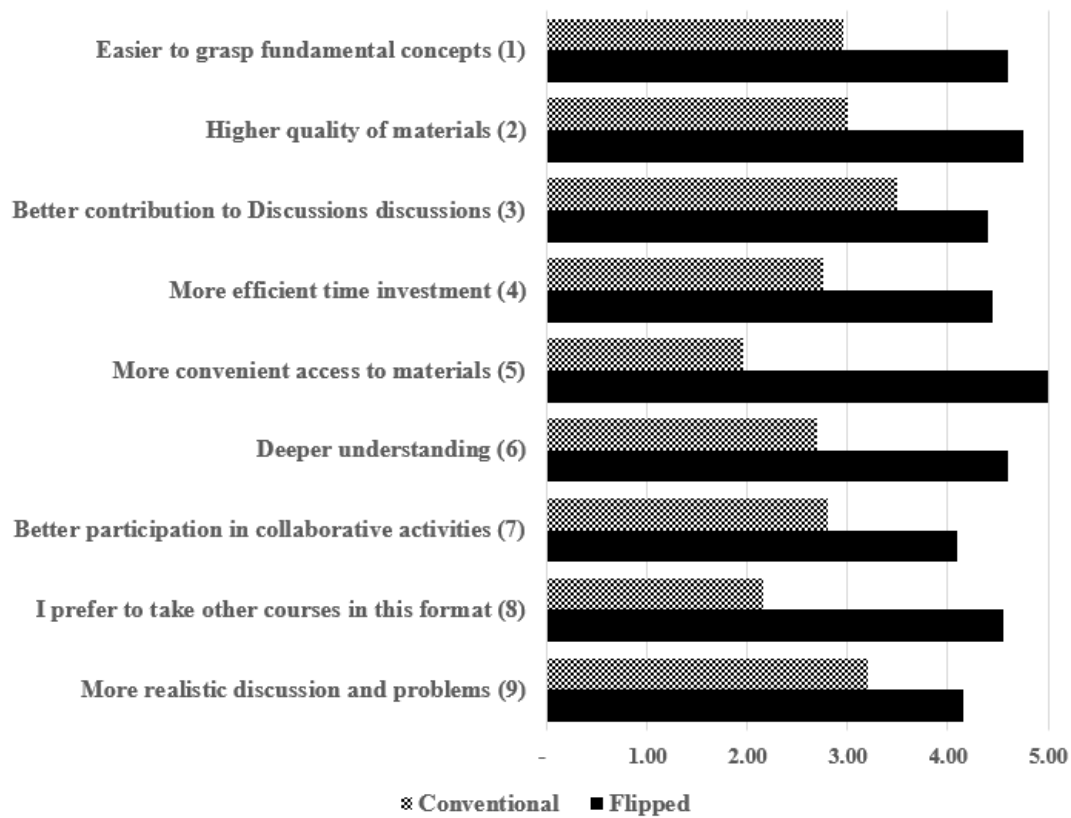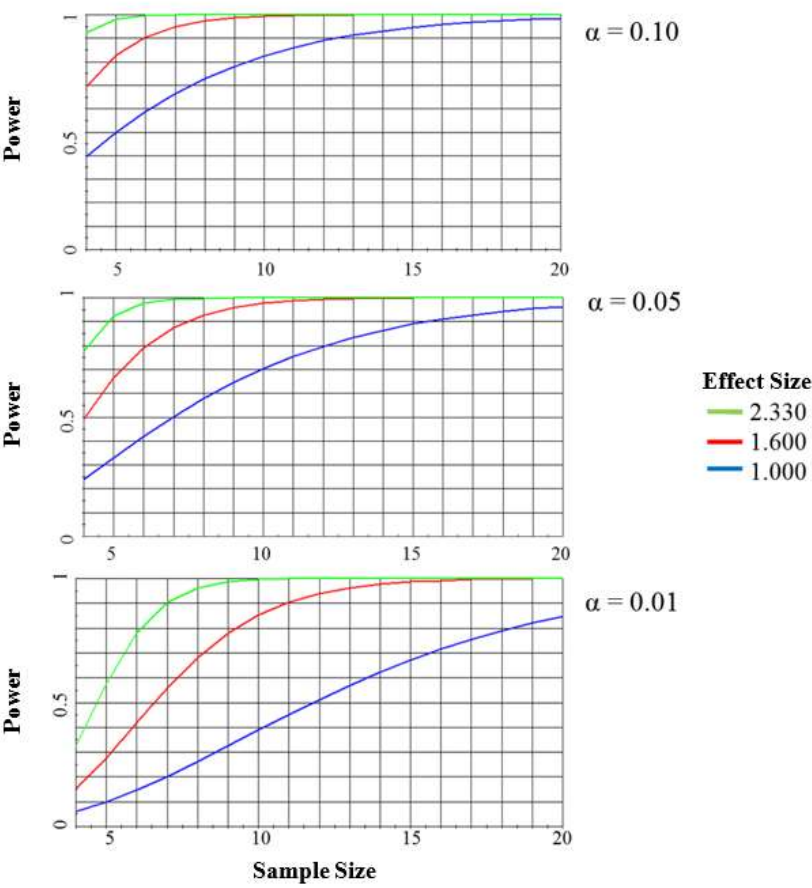
451 instruction.

26

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.

456

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