



Evolution of a Flipped Engineering Economy Course

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Abstract

This paper describes the evolution of a flipped engineering economy course over the last five semesters. Included is a description of changes made to the structure and pedagogy used in the course. Data and observations on student learning and perceptions are included.

Introduction

The flipped classroom, also referred to as the inverted/backward classroom and blended learning, is growing in use in K-12 and higher education settings, entering the “mainstream” of pedagogical approaches.¹ As a classroom model construct, it “flips” traditional in-class content delivery—thereby opening up valuable face-to-face class time for substantial formalized interaction (peer-to-peer and student-to-instructor). Using this model students access course content through videos (videos, podcasts, audiographs, vodcasts, and/or webinars²) and archived on-line course materials prior to each class session on their own time.^{3,4} Active-learning, cooperative learning, collaborative learning and problem-based learning techniques^{5,6} are then used in class to confirm, add-to, clarify, integrate, evaluate, synthesize and assess student learning. In this way the traditional model with in-class lectures and out-of-class activities (homework, etc.) is “flipped” so that content is consumed outside of class and activity and interaction is done in class.

Several advantages of the flipped model have been suggested by adopters and proponents. Mason⁷ suggests three primary benefits: (1) it frees class time for important social learning interactions with peers, and instructors, (2) it creates an archived record of class materials available on course management systems to accommodate differing student learning styles and flexible scheduling, and (3) it encourages students to think of themselves as life-long learners⁸. In addition, the flipped construct is suggested as being adaptive to the needs of millennial learners.⁹ As a teaching and learning model the flipped structure is not without criticisms and misunderstandings¹⁰; however, it is a model gaining substantial broad-based adoption across disciplines and educational levels.

Background

The civil, construction and environmental engineering faculty at NC State University have historically recognized the important place of engineering economic analysis concepts within the BS curriculum. Students’ mastery of basic engineering economy principles for professional and personal use are judged important by the faculty—in addition they are included on the Fundamentals of Engineering (FE) exam by most engineering disciplines.¹¹ Most recently this material has been implemented in the department’s curricula as a one semester-credit hour course, *CE 390: Engineering Economy*, required of all students in the civil, construction, and environmental programs in the department. The course, which was first offered in a traditional lecture format in Fall 2009, is offered in both fall and spring semesters each year with enrollments ranging from a low of 75 to a high of 102 students. In Fall 2012 the course was converted to a flipped classroom structure utilizing a Moodle course management website with on-line reference materials and instructional videos.¹² The course model was changed in an effort to increase student learning, and engagement and commitment to the materials.

Evolution of CE 390

Over the course of the five semesters since the course was initially flipped (Fall 2012 to Fall 2014 semesters) there has been an evolution of certain elements of the course. Over this timeframe, certain changes made were in response to the instructional team's observations and student feedback. Table 1 provides a summary of the basic elements of the course, including those things that remained consistent and those that were adapted over the five semesters. Table 2 illustrates the course changes and timing.

Table 1: Consistent and changed course elements

Consistent course elements:

- In each of the five semesters we used a consistent blocking of course materials into 12 units of instruction (corresponding to 12 weeks of instruction) with 12 supporting videos.
- The class on the first day was used to explain the structure of the course and answer student questions. We covered the syllabus, course structure, rules and policies, and resources.
- The final exam for the course was consistent across all five semesters. It was comprehensive and formatted as working problems of various types. These exams were graded by hand by the same instructor, applying partial credit as appropriate.
- For all five semesters the same course grade scale was used to assign letter grades (plus-minus grading scale applies) to students and the same instructor set the grading scale.
- In all semesters, both instructors as well as teaching assistant (TA) were available to work with students one-on-one, in scheduled study group time, during active learning sessions, etc.

Course elements that changed:

Attendance:

- The requirement to attend the weekly class meetings was part of the grade scale in a single semester in the others it was not. In most cases attendance was 100% elective for the entire semester.

Practice Exams:

- In some cases we did not offer practice exams, in most we did have them available. For a couple of semesters we required that students complete practice exams and a portfolio book to qualify to take practice exams, which in turn were required to qualify to sit for the final exam.
- The practice exams have been developed as dynamic questions administered on the course Moodle page. Each student receives unique number values in the problems, which are completed by students on their laptops. In some semesters the practice exams were completed wherever the students wanted to take them, in the last two semesters we have required students to come to class to take these practice exams.

Course Grading Policy:

- In the initial semester we used a distributed course grade scale that included elements of exams and participation, the middle semesters used a 100% weight in the final exam scheme, and the most recent two semesters we returned to a somewhat distributed scale.

Required Work:

- In the initial semester we required participation in the active learning sessions. Later students were required to complete practice exams and portfolio books in order to qualify for the graded portions of the class.

Final Exam Timing:

- As a twelve week course within a 15 week semester we initially held the final exam during finals week, along with students' other exams. Later we changed this element by moving the exam closer to the end of the course content and before the final exam period. More recently we moved it back to the final exam schedule.

Table 2: Summary of course changes and timing

Semester	Grading System	Quizzes/Exams	Class Sessions
Fall 2012	Class Sessions – 25% Midterm Exam – 35% Final Exam – 40%	Midterm and Final Exam were in-class written exams in a traditional format, graded for correctness with partial credit as appropriate.	Students required to attend class sessions, graded in-class activities.
Spring 2013	Final Exam – 100%	Two non-required Practice Exams were available for students. Practice exams were paper exams done outside of class. These and the Final Exam were formatted and graded for correctness with partial credit as appropriate.	No required class sessions, optional work sessions available for students with faculty and TA.
Fall 2013	Final Exam – 100%	Practice exams and portfolio required to qualify for Final Exam. Practice exams were laptop computer generated and done outside of class. Final Exam was in-class in a traditional format, graded for correctness with partial credit as appropriate.	No required class sessions, optional work sessions available for students with faculty and TA.
Spring 2014	Final Exam – 100%	Practice exams and portfolio required to qualify for Final Exam. Practice exams were laptop computer generated and done outside of class. Final Exam was in-class in a traditional format, graded for correctness with partial credit as appropriate	No required class sessions, optional work sessions available for students with faculty and TA.
Fall 2014	Quiz #1 – 10% Quiz #2 – 10% Final Exam – 80%	Quizzes were in-class, laptop generated and graded for no partial credit. Practice quizzes in the same format were given one week prior to each quiz. Final Exam was in-class in a traditional format, graded for correctness with partial credit as appropriate	No required class sessions, optional work sessions available for students with faculty and TA.

In the sections below we trace the past five semesters of this flipped course, providing details and data from each offering. Data is drawn from course grades, standard university course evaluations, and an on-line anonymous course survey administered at the end of each semester. Table 3 below provides the number of students enroll in each section, the number of students completing course evaluations, and the number of students completing the survey over the five semesters of flipping.

Table 3: CE 390: Engineering Economy course data

Semester	# Enrolled	# Completing Evaluations	# Completing Survey
Fall 2012	86	31	41
Spring 2013	75	35	49
Fall 2013	88	35	45
Spring 2014	85	24	-
Fall 2014	90	33	52

Fall Semester 2012

Structure: The fall semester of 2012 was the first semester in which *CE 390: Engineering Economy* used a flipped classroom structure. The grading component and basic course requirements were informed from earlier teachings of the course using a traditional classroom structure. Grading was based on three components: Classroom participation in the active learning sessions (25% of the final grade), a single midterm exam (35% of grade), and a final course examination (40% of grade). An attendance policy required students to attend all sessions, and the mid-term and final exams were of a traditional format in both administration and manner of grading—they were paper and pencil format and partial-credit grading was used as appropriate.

Results: Student final grades from this first flipped iteration were similar to final grades from the previous three lecture-format offerings (see Table 4). However, when examining the number of students earning a D or F grade, more students from the flipped classroom earned lower than a C in the course when compared to the average of the three previous course offerings ($p < 0.001$ ($\chi^2 = 39.53$, $df = 16$)).

Table 4: Final Course Grades, Fall 2009 to Fall 2012

	Percentage of Students Receiving Grade					
	A	B	C	D	F	Other
Fall 2012	12	23	23	24	16	2
Spring 2011	14	21	35	23	6	1
Spring 2010	15	21	30	21	13	0
Fall 2009	15	24	31	19	9	2

Student course evaluations of the flipped structure were consistent with previous semesters using a lecture format across three important questions from the evaluation (see Table 5).

**Table 5: Average Course Evaluation Comparison
Fall 2009 to Fall 2012 (1=strongly disagree to 5=strongly agree)**

	Fall 2012	Spring 2011	Spring 2010	Fall 2009
Course assignments were valuable	3.2	3.4	3.1	3.0
Course improved my knowledge	3.3	3.3	3.2	2.9
Overall, this course was excellent	2.5	2.3	2.4	2.0

Results from the on-line anonymous student survey indicated that a number of desirable outcomes were being achieved. For instance, a large percentage of students indicated that the course structure forced them to engage in independent work and learning, as well as also seeing benefit and value in the course reference materials, lecture notes and videos. However, there was also information from the survey that indicated students did not see the course format in a positive light. A high number of students indicated that the course in flipped format required too much time. Almost 75% of students desired “not” to see the format used in other courses in the curriculum, and that they “did not like” the structure of the course.

Analysis: Collectively, this information indicated mixed success from the first iteration of the course. Student grades and course evaluation data were similar to previous offerings—with the exception of the increase in D/F grades. The survey probed important elements that the standard university course evaluation did not (see Lavelle et al.¹²), and indicated student satisfaction with some elements (videos and materials) and less for others (time required, overall structure). These effects were considered, along with the instructors’ overall perceptions of this first iteration of flipping, in planning for spring 2013.

Spring Semester 2013

Structure: Several key changes to the structure of the course were implemented in spring 2013. Class attendance was made optional in this semester, and “optional work sessions” with the instructors/teaching assistant were substituted and made available to students. This change was implemented in response to student feedback on the time required in the course. The change was also made in an effort to encourage students toward self-empowered learning, and strengthening their skills related to ABET Criterion 3(i) “a recognition of the need for, and an ability to engage in life-long learning.”¹⁴ With this in mind, and considering the format of the Fundamentals of Engineering Exam¹⁵, the grading structure was also modified so that the entire grade was based on the final exam. To assist students in preparing for the final exam and provide feedback on their learning through the semester, two optional practice exams were provided. These exams were graded and provided the basis for students to obtain feedback and work on deficient learning areas.

Results: Of note this semester was the particularly high percentage of students who failed the course. Additionally, the grade distribution of the fall 2012 and spring 2013 offerings differed significantly from one another ($\chi^2 = 20.96, df = 5, p < 0.01$), see Table 6. By examining the standardized residuals we found that the single largest difference in grade distributions was between the numbers of students earning an F grade. Meanwhile, the number of students earning a C and D in spring 2013 was substantially fewer than fall 2012. The observed differences in students earning an A and B were negligible.

Table 6: CE 390: Engineering Economy Grade Distribution, Fall 2009 to Spring 2013

	Percentage of Students Receiving Grade					
	A	B	C	D	F	Other
Spring 2013	8	16	13	13	50	0
Fall 2012	12	23	23	24	16	2
Spring 2011	14	21	35	23	6	1
Spring 2010	15	21	30	21	13	0
Fall 2009	15	24	31	19	9	2

Despite the rise in students earning an F grade, the course evaluations for spring 2013 were on par with previous semesters (see Table 7)—a one-way ANOVA confirmed the lack of variability in course evaluation responses.

**Table 7: Average Student Evaluation Comparison, Fall 2009 to Fall 2012
(1=strongly disagree to 5=strongly agree)**

	Spring 2013	Fall 2012	Spring 2011	Spring 2010	Fall 2009
Course assignments were valuable	3.5	3.2	3.4	3.1	3.0
Course improved my knowledge	3.3	3.3	3.3	3.2	2.9
Overall, this course was excellent	2.3	2.5	2.3	2.4	2.0

In the spring 2013 anonymous student survey three questions were focused on in particular. The first asked students to indicate if the flipped structure resulted in them being more engaged with course material—recall from the previous semester that students did not like this structure. A clear and distinct negative response was observed (see Figure 1). A chi-square analysis tested for statistically significant differences in the question response patterns between fall semester 2012 and spring 2013 respondents resulted in no differences ($\chi^2 = 4.87, df = 4, p > 0.05$).

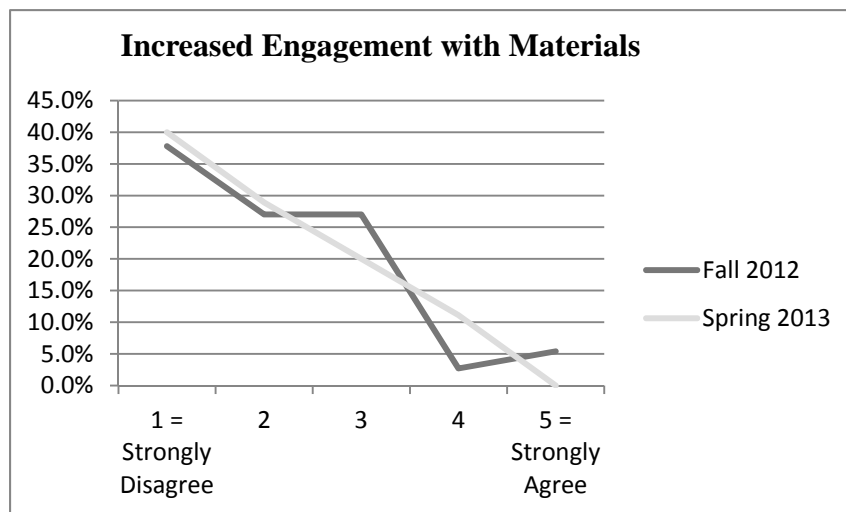


Figure 1: Student Engagement from Survey, Fall 2012 to Spring 2013

The second question asked students if the flipped structure resulted in them taking more responsibility for learning in their courses (see Figure 2). No statistically significant differences were observed among the responses for this item when comparing fall 2012 and spring 2013 ($\chi^2 = 3.51, df = 4, p > 0.05$).

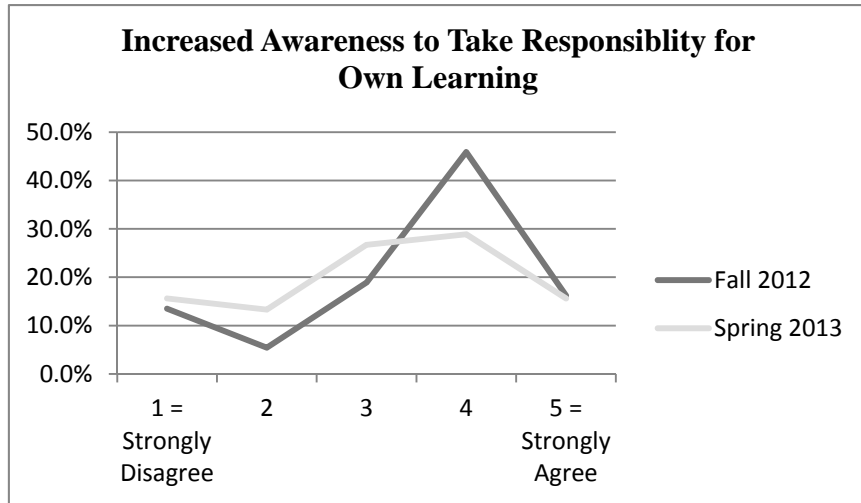


Figure 2: Student Responsibility from Survey, Fall 2012 to Spring 2013

The final question asked students if they prefer the flipped model over the traditional model (see Figure 3). As was observed in the previous two items, no statistically significant differences were observed between the semesters ($\chi^2 = 6.73, df = 4, p > 0.05$).

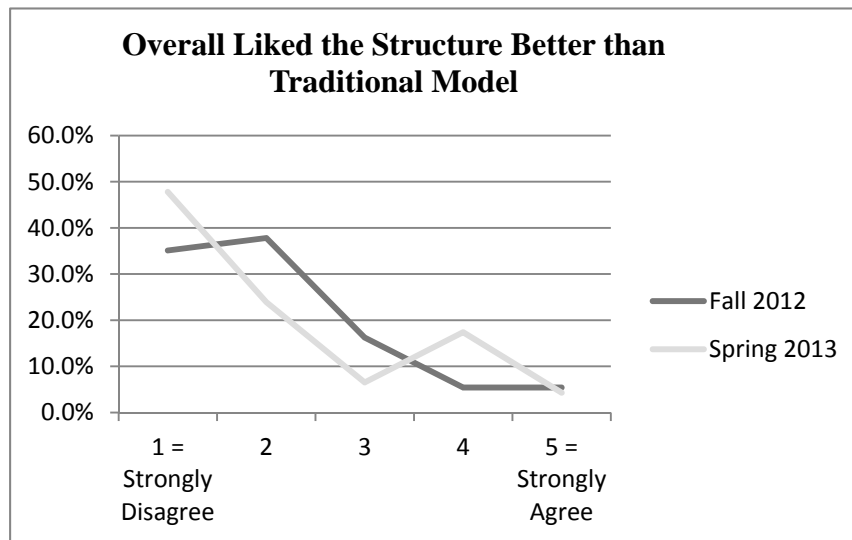


Figure 3: Liked Structure from Survey, Fall 2012 to Spring 2013

Analysis: In this iteration of the course several important changes were made; however, none of these created changes in students’ assessment of the course as measured by the anonymous survey. Their feedback related to engagement with the materials, knowledge of need for self-directed learning, and the flipped structure versus lecture format all remained negative. The course grade distribution and standard course evaluations provided no indication of change, with the exception of more F grades in the Spring 2013 semester. The number of F grades was problematic for the instructors, who decided that there was a need to provide more structure to keep students engaged with the course and guide them through it.

Fall Semester 2013 and Spring Semester 2014

Structure: The 2013 fall and 2014 spring semester course offerings kept many of the changes that were employed in spring 2013. This included optional weekly class attendance and a final grade that was based entirely on the final exam. However, one substantive change that was made during this semester was to require practice exams and a course portfolio. These elements were required of students to be eligible to take the final exam. While the portfolio and practice exams were not part of student grades, we believed them to be an important determinant of learning and as a result required their completion. We had previously dropped all required elements within the semester to the detriment of student engagement with the materials. This change was made to re-engage students with the materials.

Results: Final grades for fall 2013 and fall 2014 semester are listed in Table 8, and the distributions did not differ significantly ($\chi^2 = 5.16$, $df = 4$, $p > 0.05$). Moreover, a comparison of grade distributions from spring 2014 and spring 2013 yielded no statistically significant differences ($\chi^2 = 6.01$, $df = 4$, $p > 0.05$). However, in both semesters the number of F grades were improved compared to the spring 2013 semester.

Table 8: CE 390: Engineering Economy Grade Distribution, Fall 2009 to Spring 2014

	Percentage of Students Receiving Grade					
	A	B	C	D	F	Other
Spring 2014	8	25	19	16	31	1
Fall 2013	9	26	15	15	32	3
Spring 2013	8	16	13	13	50	0
Fall 2012	12	23	23	24	16	2
Spring 2011	14	21	35	23	6	1
Spring 2010	15	21	30	21	13	0
Fall 2009	15	24	31	19	9	2

Class evaluations from fall 2013 and spring 2014 were again on par with evaluations from previous semesters (see Table 9). None of the observed differences in class evaluations differed significantly.

**Table 9: Average Student Evaluation Comparison, Fall 2009 to Spring 2014
(1=strongly disagree to 5=strongly agree)**

	Spring 2014	Fall 2013	Spring 2013	Spring 2012	Spring 2011	Spring 2010	Fall 2009
Course assignments were valuable	3.4	4.0	3.5	3.2	3.4	3.1	3.0
Course improved my knowledge	3.4	3.7	3.3	3.3	3.3	3.2	2.9
Overall, this course was excellent	2.8	3.1	2.3	2.5	2.3	2.4	2.0

While we do not have student survey data from the spring 2014 *CE 390: Engineering Economy* class, we do have survey data from the fall 2013 iteration of the course. A continued negative assessment was observed on the item related to increasing engagement in materials (see Figure 4). Yet, none of the changes observed in the item responses differed significantly ($\chi^2 = 13.91$, $df = 8$, $p > 0.05$).

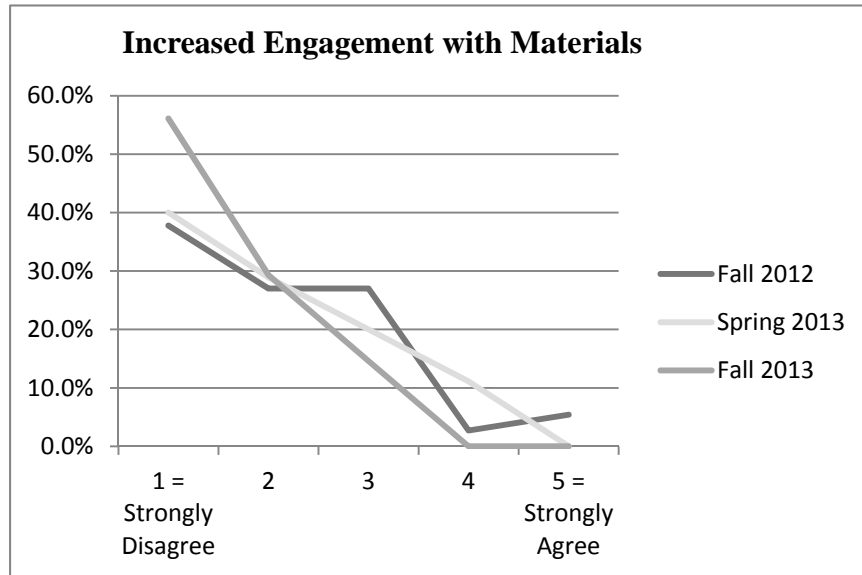


Figure 4: Student Engagement from Survey, Fall 2012 to Fall 2013

A similar shaped distribution was observed relative to the “students taking responsibility for own learning” question (see Figure 5). While the number of students indicating agreement with the statement from fall 2013 did not reach the level of fall 2012, a Chi Square analysis indicated that none of the observed differences rise to a level of statistical significance ($\chi^2 = 8.08$, $df = 8$, $p > 0.05$).

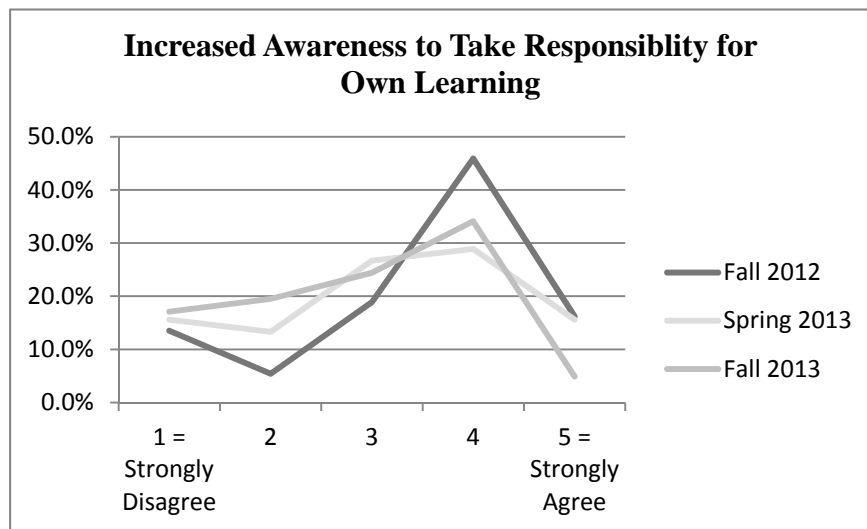


Figure 5: Student Responsibility from Survey, Fall 2012 to Fall 2013

Finally, in aggregate, students from the fall 2013 section continued to indicate a dislike of the flipped structure compared to the traditional model (see Figure 6). A higher percentage of students from fall 2013 indicated strong disagreement than observed in previous semesters, and the observed distributions among the fall 2012, spring 2013, and fall 2013 respondents differed significantly, with a higher percentage of students indicating strong disagreement. ($\chi^2 = 17.08$, $df = 8$, $p < 0.05$).

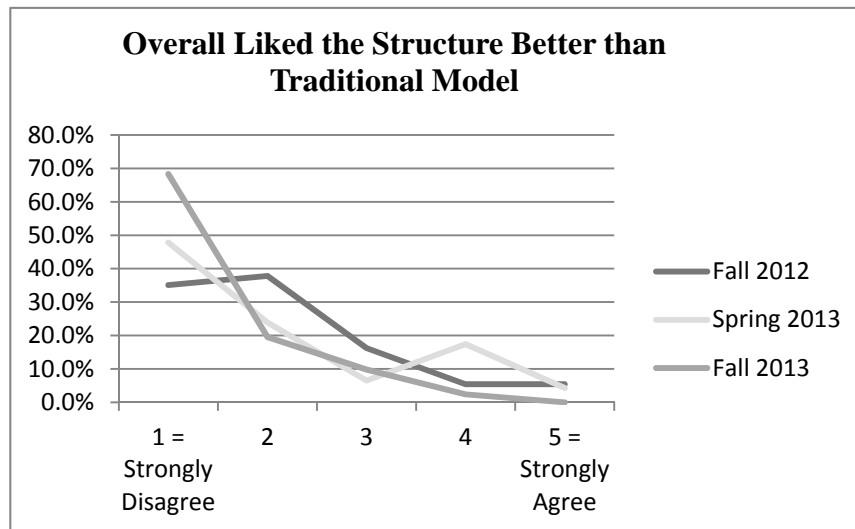


Figure 6: Liked Structure from Survey, Fall 2012 to Fall 2013

Analysis: Course data from the fall 2013 and spring 2014 semesters seem to indicate no substantive change in student evaluations and performance. The number of F grades did improve when compared to spring 2013, but overall student survey response feedback was negative relative to the flipped structure, engagement and awareness of self-learning.

Fall Semester 2014

Structure: The most recent offering of this course continued use of a final exam and optional class attendance. We also continued to utilize optional work sessions with a faculty member or TA. A shift was made, though, in the grading structure by stepping away from a final grade determined solely by a final exam. Instead, students were required to complete two in-class quizzes (each worth 10% of the grade), in addition to a final exam that accounted for 80% of the final grade.

Results: As in Table 10, course grades from fall semester 2014 did not differ significantly from spring 2014 grades ($\chi^2 = 4.91$, $df = 4$, $p > 0.05$). However, the percentage of students earning As was the highest observed, and the number of students earning an F was the lowest observed since fall 2012 when the course was converted to a flipped structure.

Table 10: CE 390: Engineering Economy Grade Distribution, Fall 2009 to Fall 2014

	Percentage of Students Receiving Grade					
	A	B	C	D	F	Other
Fall 2014	17	22	26	15	19	1
Spring 2014	8	25	19	16	31	1
Fall 2013	9	26	15	15	32	3
Spring 2013	8	16	13	13	50	0
Fall 2012	12	23	23	24	16	2
Spring 2011	14	21	35	23	6	1
Spring 2010	15	21	30	21	13	0
Fall 2009	15	24	31	19	9	2

As in previous semesters the course evaluations were relatively unchanged with none of the observed differences being statistically significant (see Table 11).

Table 11: CE 390: Engineering Economy Grade Distribution, Fall 2009 to Fall 2014

	Fall 2014	Spring 2014	Fall 2013	Spring 2013	Spring 2012	Spring 2011	Spring 2010	Fall 2009
Course assignments were valuable	3.7	3.4	4.0	3.5	3.2	3.4	3.1	3.0
Course improved my knowledge	3.5	3.4	3.7	3.3	3.3	3.3	3.2	2.9
Overall, this course was excellent	2.8	2.8	3.1	2.3	2.5	2.3	2.4	2.0

Meanwhile, students continued to indicate that the course materials were not resulting in increased engagement with materials. However, fewer students in fall 2014 indicated strong disagreement when compared to fall 2013 respondents (see Figure 7), although the difference was not large enough to be statistically significant. When examining the response patterns among all four semesters, no statistically significant differences were observed ($\chi^2 = 16.79$, $df = 12$, $p > 0.05$).

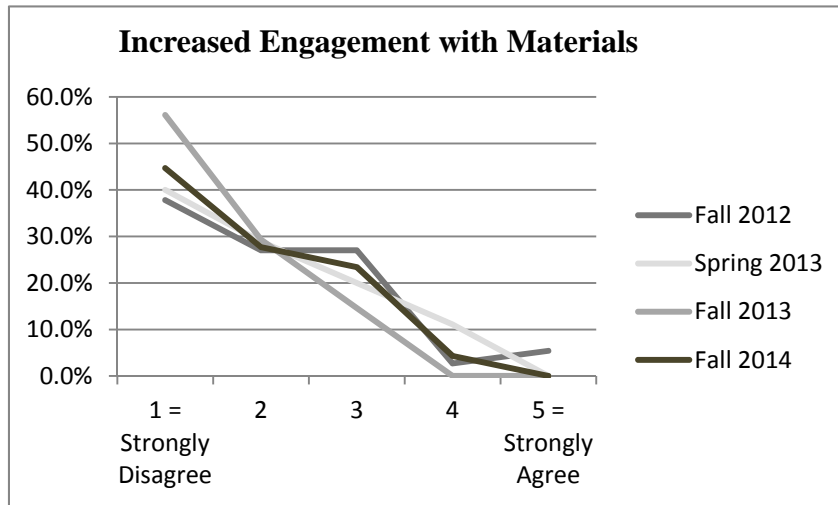


Figure 7: Student Engagement from Survey, Fall 2012 to Fall 2014

From Figure 8 response patterns from fall 2014 respondents on increased awareness to responsibility for own learning were also similar to other semesters, with no statistically significant findings ($\chi^2 = 9.30, df = 12, p > 0.05$).

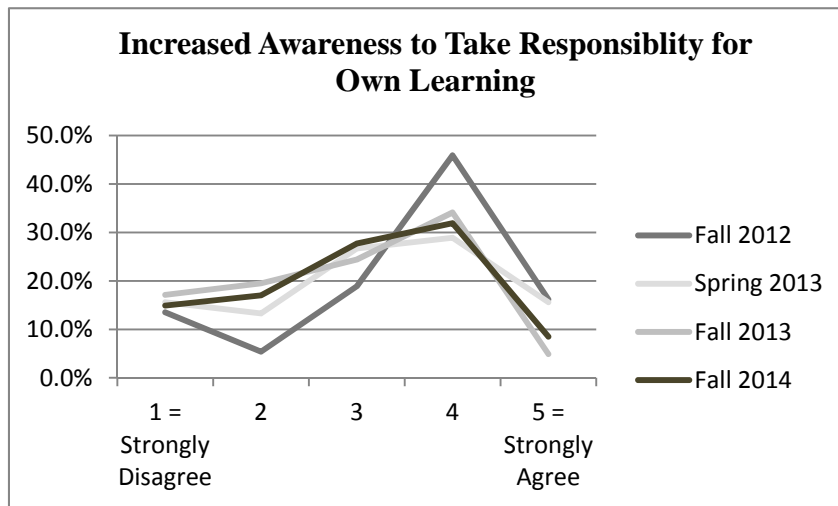


Figure 8: Student Responsibility from Survey, Fall 2012 to Fall 2014

Finally, per Figure 9, fewer students from fall 2014 indicated strong disagreement related to preferring the flipped structure to a traditional model, when compared to respondents from fall 2013. Yet, the observed differences among all respondents did not vary statistically ($\chi^2 = 20.14, df = 12, p > 0.05$).

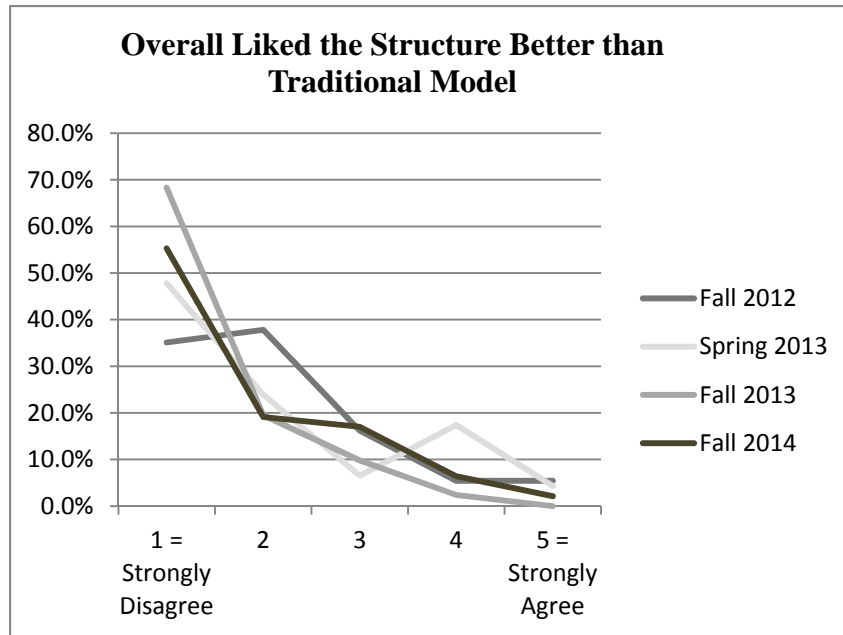


Figure 9: Liked Structure from Survey, Fall 2012 to Fall 2014

Analysis: The instructors were optimistic about the fall 2014 semester offering of the course, particularly related to student grades. Although not statistically significant, the percentage of A grades and F grades were at all-time bests since the course was flipped. Students continue to express negative feedback on the course via the student survey, however, standard course evaluations were positive and in line with lecture-style measures.

Major Finding and Discussion

The *CE 390: Engineering Economy* course is an important required element in the civil, environmental and construction engineering curricula at NC State University. First organized in a flipped structure in fall 2012 the course has undergone several changes over the past offerings. Data drawn from course grades, standard university course evaluations and an anonymous course survey provide a longitudinal overview of the course over the last five semesters. The following are the main observations from this data:

- Flipped Structure: Over the period of the past five years students have reported a consistent negative response to the flipped class structure, with no statistically significant change over that time. Students' assessment of flipping has not changed despite varying the requirement for in-class activities and class attendance, changes to the grading structure for the final grade, and the availability and requirements for practice exams and portfolios.

In considering this observation several factors come to mind. First, students in the College of Engineering at NC State University are only now beginning to confront the flipped classroom structure, and within the CCEE department this course is one of the few experimenting with this structure. As a result students have not perhaps adapted to this learning paradigm. A second consideration relates to students' perceptions of the *CE 390: Engineering Economy* course itself. There was an indication previous to implementing flipping that students did not like this course. As a one credit-hour course taken in difficult

semesters by juniors and seniors it was perhaps not given attention (and thus not liked) by students. Lastly, despite the instructors good intentions regarding adjustments to the course structure, perhaps we have not yet found the right balance of parameters yet. From the anonymous survey students' dislike for this structure has increased each iteration until fall 2014 when it reduced slightly. In addition, fall 2014 brought best levels of A and F grades. Thus, perhaps the course is now trending toward a status that promotes higher levels of student achievement.

- Standard Course Evaluations: Each semester students are asked to complete standard evaluations in all of their courses at NC State University. Over the five semesters of the flipped versions of *CE 390: Engineering Economy* the student evaluations of the course did not change. As a result data from this instrument provide limited feedback for the instructors in evaluating the impact of the flipped course.

The situation with evaluations is not unexpected as this tool does not target specific elements of course structure. In addition, based on the limited percentage of students who complete the evaluation one should be cautious in over-assigning meaning to summary statistics. What is often more useful from these evaluations are the written feedback when students take the time to articulate things that were done well and areas for improvement.

- Course Grades: With one exception, the distribution of final course grades did not change, statistically over the course of the flipped implementation. As was noted previously in spring 2013, a larger number of F grades were earned by students, and in fall 2014 a record high percentage of As and low percentage of Fs were given.

Whereas grades are not a first order focus, if they are accurate measures of students learning they are important. Student re-take rate was one of the initial noted concerns for *CE 390: Engineering Economy*, so there is desire to improve the percentage of students receiving a grade of C or better.

Conclusion

The *CE 390: Engineering Economy* course at NC State University was initially converted to a flipped structure in fall 2012. Over the last five semesters the instructors have adjusted several parameters within the class in an effort to improve student engagement and commitment to the materials, learning, and course grades. Thus far, the factors tested have not improved these metrics; however, the recent semester (fall 2014) provided encouraging results. Complicating conclusions concerning the effects of flipping the course were existing student attitudes toward the course. The instructors continue to work to understand and redirect attitudes and behaviors in support of improved performance.

Plans for future semesters include re-instituting active learning based weekly sessions in some format, providing and improving on-line instructional resources such as dynamic homework with feedback.

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