To Flip or Not to Flip

Active and Collaborative Learning

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***Abstract*—The flipped classroom is gaining popularity as a teaching strategy that allows instructors to create an active learning environment. It focuses the responsibility of learning on the students and changes their role from listeners to learners. In a previous paper the authors presented an example of a flipped-classroom approach to a one-semester "Fundamentals of Digital Design" required course for Electrical and Computer Engineering majors in order to lower its failure rate and to further motivate students so as to improve overall attrition. The authors used the Livescribe™ paper-based computing platform which consists of a digital pen, Anoto™ digital paper, software applications, and developer tools to create the online recorded lectures and problems which were uploaded to "Blackboard" for students to view and solve at home. The authors used this technology as well as the concept of "Just-in-Time Teaching" (JiTT) to provide the "feedback loop" to affect what happens during the subsequent in-class time together. The authors concluded that while the flipped version of EENG 125 "Fundamentals of Digital Logic" succeeded in improving student retention and while the approach was popular with students, with respect to class averages and standard deviations, the results were not much better than in a traditional classroom which incorporated a high level of active learning activities. As a result, the authors decided to incorporate student groupings that are heterogeneous, so as to provide each student an opportunity to work through problems both independently and in collaboration with their peers as well as Out-of-Class Assessment Techniques (OoCATs) such as the "Minute Paper" and the "Muddiest Point" to provide the authors with useful feedback with regard to the recorded lectures and problem solving assignments. The authors would then assess this new flipped version of EENG 125 with the traditional and active learning versions of the course.**

Keywords—Just-in-Time Teaching (JiTT); Livescribe™; minute paper; muddiest point

I. Introduction

The traditional pattern of teaching at both the college level and K-12 institutions has been one in which the instructor typically assigns students to read textbooks and to work on problem sets outside the class, while listening to lectures and taking tests in class. This is often referred to as passive learning and it is associated with students taking notes and essentially acting as "scribes". While lectures delivered by talented instructors can be highly stimulating; and at the very least, provide an efficient way of introducing large numbers of students to a particular field of study, critics of passive learning say that students are not really learning but just memorizing or retaining enough information to pass their next test.

Active learning, on the other hand is an instructional methodology which places more emphasis on the interaction of students with their instructor through in class activities that ask them to retrieve, apply, and/or extend the material learned in class. Students are expected to reflect on what they have been taught and by drawing students into the process, provide a meaningful learning experience. In particular, traditional lectures often supplement their in class activities with interactive software, web-based materials and a laboratory component, all of which are intended to generate excitement and motivation by providing students with both heads-on and hands-on experiences. For the instructor, through both formative and summative assessments, active learning, unlike passive learning, must always be adapting, and as such is dynamic, with continual revisions to teaching and delivery methods, visual aids and demonstrations.

The flipped classroom is one of a variety of teaching strategies that allows instructors to create an active learning environment. In a study conducted by a group of faculty with the Electrical and Computer Engineering Department of the University of Florida, Gainesville, and Florida presented in the IEEE Transactions on Education, they reported significant gains in both student's performance and retention rate after flipping Circuits I class [1]. In the flipped classroom, instructors typically assign online recorded lectures as homework, and use face-to-face instruction for active learning exercises and direct engagement with students in the classroom. As such, it has the potential to provide the greatest amount of time for direct student/teacher interaction, and if students work in small groups, for peer/peer interactions as well. This interactive/social engagement between instructor and student and among peers provides immediate feedback to both the student and instructor and has been strongly correlated with retention in the discipline [2]-[5].

In the fall of 2016 semester, the authors implemented a flipped-classroom approach to a one-semester required course of logic design for Electrical and Computer Engineering (ECE) majors in order to lower its failure rate and to further motivate students so as to improve overall attrition.

II. The Institute

The Institute is a non-profit independent, private institution of higher education. Led by the President, the Institute is guided by its mission to provide career-oriented professional education, offer access to opportunity to all qualified students, and support applications-oriented research that benefits the larger world. Its students represent nearly all 50 US states and 109 countries. The total number of international students at the various domestic campuses is 1350 (~ 10% of the total student population), the majority of whom are in the School of Engineering and Computing Sciences (SoECS).

There are 960 freshman enrolled in the class of 2016. The average SAT score in Math and Critical Reading is 1120 and the average High School GPA is 89. To be admitted to engineering programs, students must have a minimum combined SAT score of 1000 (critical reading and math only), which includes a minimum of 520 in mathematics. In addition, students should have adequate mathematics courses to permit entry into Calculus I. Regardless of their SAT scores all entering freshman and transfer students who have not received transfer credit for either Mathematics or English courses must take placement exams to determine their skill in English and Mathematics. Their performance on the placement exam determines what course(s) they are eligible to take in their academic major.

In general, the students in the engineering programs are first generation college students and many of them are required to take remedial courses in Mathematics and English.

The Center for Teaching and Learning, (CTL), supports faculty members in their work as teacher-scholars by cultivating reflective practice and promoting the scholarship of teaching and learning. As part of the Institute's identity as a partially virtual institution, they serve as a resource for best practices in skillful, appropriate, and effective uses of technology in education. CTL provided assistance with the experimental procedure for the evaluation of the effectiveness of the two instructional methodologies.

III. FLIPPING THE CLASS

The Fundamentals of Logic Design course is offered every fall semester during day to the freshman in the ECE program and the authors retained the same syllabus as the traditionally taught fall 2015 version of the course.

While the fall 2015 semester course included active learning activities, the effectiveness of the two very different instructional methods were assessed in terms of student retention, performance and attitudes. The size of the class was essentially the same in both the fall 2016 and fall 2015 semesters at 27 and 25, respectively. As the course is taught every semester by the same instructor and class size over the period from fall 2014 to fall 2016 was capped at 25, and varied between 27 and 25, it was possible to use data for the traditional classes prior to the fall 2016 for assessment and comparison purposes.

The fall 2014 and fall 2015 semesters of the Fundamentals of Logic Design were taught traditionally. During each contact hour, the instructor lectured on the course material, worked out problems in the class and supplemented the student's in class activities by additional VHDL in-lab and homework assignments. Students were also given the opportunity to solve problems in class in order to provide formative feedback information [1] to the instructor. Three exams and a comprehensive final were given; and each of the three exams focused primarily on the material presented after the previous exam. However, as the material presented builds on prior concepts it should be understood that each exam required students to utilize techniques that were introduced earlier in the course.

The fall 2016 section of Digital Logic Design was taught as a flipped class. The instructor used the **Livescribe™** paper-based computing platform which consists of a digital pen, digital paper, software applications, and developer tools. Central to the **Livescribe™** platform is the smartpen, a ballpoint pen with an embedded computer and digital audio recorder. When used with **Anoto™** digital paper, it records what it writes for later uploading to a computer, and synchronizes those notes with any audio it has recorded. The instructor used this technology as well as the concept of "Just-in-Time Teaching" (JiTT) to create the online recorded lectures and problems which were uploaded to "Blackboard" for students to view and solve at home and then come to class prepared to work problems in small groups of 3 or 4 students. Of the problems solved out-of-class, some were concept-oriented and others required analytical solutions and when uploaded to Blackboard provided the instructor with the "feedback" which is at the heart of JiTT and fundamentally affected what happened during subsequent in-class time together.

In order for student results to be effectively compared, the flipped class had three exams and a final exam with a schedule and content and assessment methodology similar to previous sections of the course. In order to determine if the mean value of each exam in the flipped class was significantly different from each comparable exam in the two prior offerings of the course taught in a traditional manner we used a separate t-Test for two independent samples of different variances for each of the two prior sections. The results of these t-Tests and their corresponding p values are summarized in Table 9 below, with the actual results of the spreadsheet analysis for the various t-Tests in Tables 1 to 8 below.

Historically, there has been little difference between students in the fall semesters of this course in terms of their SAT scores and their high school grade point averages so that the only real difference between the two groups was how class time was spent, since they had the same instructor, similar lectures, and exams. It was the author's expectation that student performance would improve significantly in the flipped class when compared to each of the prior semesters and if not, why not?

IV. PERFORMANCE

In terms of student retention there was significant improvement. Of the 54 students that were enrolled in the previous 2 semesters, 5 or nearly 10% withdrew from the course before the end of the semester. All 5 students dropped because of poor performance and their having recognized that

[1] The admission requirements and information with regard to the Center for Teaching and Learning (CTL) under Section II can be found at the NYIT web page www.nyit.edu under catalog

it was highly unlikely that they would make a passing grade. The authors followed up with the registrar's office and were able to ascertain that of the 5 students, all 5 were discouraged enough to no longer pursue an electrical and computer engineering career path.

The fall 2016 retention numbers indicated that only 1 student of the 27 students which was less than 4% of the students registered for the course, withdrew before the end of the semester and that was due to poor grades. Student retention was thus more than two times greater in the flipped class than in the traditionally taught sections. We believe this was primarily the result of several factors:

1) Students had improved performance on the exams.

2) Face-to-face time with the instructor and working in small groups helped to integrate the students more thoroughly into the course and the SoECS.

An examination of the t-Test results for the three exams and the final exam in Tables 1 to 8 below, indicate that the mean was higher in the flipped version of the course in each semester with the differences in the means greatest between the fall 2016 semester and the fall 2014 semester.

As for the fall 2014, 2015 sections of the course, the means and standard deviations were such that the results for the flipped class were statistically significant for each exam. It should be noted that the syllabi for each section was the same and the rubrics for grading the exams were identical in all semesters to insure consistency in partial credit, with grading being done by the same instructor in each class. However, the main difference between the courses offered in the fall 2014 and the fall 2015 semesters was that the level of active learning was much greater in the fall 2015 semester because of both formative and summative assessment activities.

TABLE I. T-TEST, TWO-SAMPLE, UNEQUAL VARIANCES: TEST 1 FALL 2016 VS. TEST 1 FALL 2015 (ALL FIGURES IN THIS AND SUBSEQUENT TABLES HAVE BEEN ROUNDED TO TWO SIGNIFICANT FIGURES AFTER THE DECIMAL POINT)

	test 1, f16	**test 1, f15**
Mean	92.04	87.00
StDev	6.41	9.32
Observations	27	27
Hypothesized Mean Difference	0	
df	46	
t Stat	2.33	
P(T<=t) one-tail	0.01	P < .05, difference in the means is statistically significant

TABLE II. T-TEST, TWO-SAMPLE, UNEQUAL VARIANCES: TEST 1 FALL 2016 VS. TEST 1 FALL 2014

	test 1, f16	**test 1, f14**
Mean	92.04	71.92
StDev	6.41	15.04
Observations	27	26
Hypothesized Mean Difference	0	
df	33	
t Stat	4.50	
P(T<=t) one-tail	..00001	P < .05, difference in the means is statistically significant

TABLE III. T-TEST: TWO-SAMPLE, UNEQUAL VARIANCES: TEST 2 FALL 2016 VS. TEST 2 FALL 2015

	test 2, f16	**test 2, f15**
Mean	86.52	81.44
StDev	9.28	9.70
Observations	27	27
Hypothesized Mean Difference	0	
df	51	
t Stat	1.96	
P(T<=t) one-tail	0.0275	P < .05, difference in the means is statistically significant

TABLE IV. T-TEST: TWO-SAMPLE, UNEQUAL VARIANCES: TEST 2 FALL 2016 VS. TEST 2 FALL 2014

	test 2, f16	**test 2, f14**
Mean	86..52	76.43
StDev	9.28	14.35
Observations	27	26
Hypothesized Mean Difference	0	
df	42	
t Stat	3.51	
P(T<=t) one-tail	0.0005	P < .05, difference in the means is not statistically significant

TABLE V. T-TEST: TWO-SAMPLE, UNEQUAL VARIANCES: TEST 3 FALL 2016 VS. TEST 3 FALL 2015

	test 3, f16	**test 3, f15**
Mean	84.85	77.96
StDev	10.62	13.89
Observations	27	27
Hypothesized Mean Difference	0	
df	52	
t Stat	2.05	
P(T<=t) one-tail	0.0231	P < .05, difference in the means is statistically significant

TABLE VI. T-TEST: TWO-SAMPLE, UNEQUAL VARIANCES: TEST 3 FALL 2016 VS. TEST 3 FALL 2014

	final, f16	**final, f14**
Mean	84.85	72.69
Variance	10.62	14.57
Observations	27	26
Hypothesized Mean Difference	0	
df	45	
t Stat	3.46	
P(T<=t) one-tail	0.0006	P < .05, difference in the means is statistically significant

TABLE VII. T-TEST: TWO-SAMPLE, UNEQUAL VARIANCES: FINAL FALL 2016 VS. FINAL FALL 2015

	final, f16	**final, f15**
Mean	86.31	81.24
StDev	8.57	11.50
Observations	26	25
Hypothesized Mean Difference	0	
df	44	
t Stat	1.78	
P(T<=t) one-tail	0.04	P < .05, difference in the means is statistically significant

TABLE VIII. T-TEST TWO-SAMPLE, UNEQUAL VARIANCES: FINAL FALL 2016 VS. FINAL FALL 2014

	final, f16	**final, f14**
Mean	86.31	72.78
StDev	8.57	16.11
Observations	26	23
Hypothesized Mean Difference	0	
df	32	
t Stat	3.60	
P(T<=t) one-tail	0.0005	P < .05, difference in the means is statistically significan

TABLE IX. BELOW SUMMARIZES THE RESULTS FROM THE 4 COURSE EXAMS FOR EACH OF THE FALL 2014 TO FALL 2016 SEMESTERS

Exam	**Mean**	**T Stat, p**	**StDev**
Test 1			
f14	71.92	4.50, .00001	15.04
f15	87.00	2.33, .01	9.32
f16	92.04		6.41
Test 2			
f14	76.43	3.51, 0.0005	14.35
f15	81.44	1.96, .0275	9.70
f16	86.52		9.28
Test 3			
f14	72.69	3.46, .0006	
f15	77.96	2.05, .0231	13.89
f16	84.85		10.62
Final exam			
f14	72.78	3.60, .0006	16.11
f15	81.24	1.78, .04	11.50
f16	86.31		8.57

V. CONCLUSION

The 2016 flipped version of EENG 125 "Fundamentals of Digital Logic" succeeded in improving student retention and the approach was popular with students. With respect to class averages and standard deviations the results were even much better than in a traditional classroom which incorporated a high level of active learning activities. The question we asked ourselves was "Why?" This should not be confused with the challenges the authors discussed in the earlier paper, but instead should be looked at as modifications to the methodologies we used in our first attempt at a flipped classroom. The following modifications are an important part of any summative assessment if we are to achieve "continuous improvement".

Collaborative learning activities are one way to accommodate the varying ability levels of students during in-class activities. In the last paper, we let the students choose their own groupings and the groups remained consistent throughout the semester. The learning abilities in these groupings were both heterogeneously and homogeneously distributed as determined by the students' Grade Point Averages (GPAs).

However, the question of whether to group students by ability levels was an interesting one and the authors found that those groups which were heterogeneous with respect to learning abilities fared much better than those that were homogeneous with respect to achievement or language proficiency levels. This was surprising because it was felt that by grouping students with similar needs, the instructor could more efficiently target those needs the students had in common and help the student to achieve at higher levels.

Research [6]-[8] have shown that student groupings that are heterogeneous, provide each student an opportunity to work through problems both independently and in collaboration with their peers. In the fall 2016 version of the flipped class, we formed only heterogeneous groups that included one student that was high achieving, two students that achieved at an average level and one student that was lower achieving with the idea that each student benefits from having the other students in the group. The variety of ideas and perspectives, as well as the shared learning was expected to benefit each student in the group. In the future we will test the student's learning styles at the beginning of the semester to help form heterogeneous teams based on the Myers-Briggs, Kolb, Gardner's Multiple Intelligences, VAK, tests [9].

The incorporation of Out-of-Class Assessment Techniques (OoCATs) which are simple, non-graded, and usually anonymous; out-of-class activities were designed to provide the instructor with useful feedback with regard to the recorded lectures and problem solving assignments. They are not to be confused with the JiTT activities.

The two most commonly used examples of OoCATs that were used were the "Minute Paper" [10] and the "Muddiest Point" [11]. The "Minute Paper" asks the student to answer two very basic questions:

- "What was the most important thing you learned during each of this week's out-of-class activities?"

And;

- "What important questions remain unanswered?"

The "Muddiest Point" helps the instructor assess where students are having difficulties. The technique consists of asking students to jot down a quick response to one question: "What was the muddiest point in the lecture or homework assignment?"

We will continue to utilize all of the above strategies in the following fall 2017 offering of the course with the expectation that students will learn the material more effectively.

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