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Impact of varying in-class time on student performance and attitudes in a flipped introductory computer programming course

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Abstract

This paper builds upon an earlier study investigating the impact of a flipped classroom format on student performance and perceptions in an introductory computer programming course for mechanical engineers at California State Polytechnic University, Pomona (Cal Poly Pomona). In the previous study, moving from a traditional lecture format (which met 100 min/week) to a flipped classroom format (which met 75 min/week) did not hurt academic performance and students had an overwhelming positive experience in the flipped section. However, the sample size was small and it was the author's first time teaching a flipped course. The current study has two goals: (1) Gather additional data by repeating the experiment using lessons learned from the previous study; (2) Examine the impact of varying the amount of in-class time on both flipped classroom sections and traditional lecture sections. Data was collected during Fall Quarter 2014 and Winter Quarter 2015 in four sections: Two sections were taught in a traditional lecture format (one section met twice per week for 50 minutes and the other section met once per week for 110 minutes) and two sections were taught in a flipped classroom format (one section met once per week for 75 minutes and the other section met once per week for 110 minutes). In the flipped sections, students were required to watch short video tutorials prior to each class meeting and given quizzes in class to ensure compliance. Class time was used for example problems and "Team Battles," an active learning exercise where student teams competed against each other to complete programming assignments for prizes. Academic performance on six quizzes and exams were compared and it was found that the flipped sections generally outperformed the traditional lecture sections on the high-stakes assessments (midterm and final exams), resulting in a noticeable difference in the overall course grades – in both flipped sections at least 50% of students received an A- or A, while less than 20% of students in the traditional lecture sections received an A- or A. Additionally, students in the flipped section that met for 110 min/week generally outperformed all other sections on the quizzes and exams. Pre-course and post-course surveys revealed that students in all four sections found the video tutorials helpful and their opinion about computer programming improved by the end of the course. Students in the flipped sections overwhelmingly enjoyed the Team Battles and felt they were effective, and thought the amount of in-class time was sufficient to learn the material.

1.1 Description of flipped learning

The past decade has seen the proliferation of technologies that have allowed instructors to experiment with novel methods of teaching. User-friendly recording software such as Camtasia Studio[1] allows instructors to develop video tutorials easily, which can be uploaded to their local LMS or YouTube with just a few clicks. One pedagogical strategy that often takes advantage of these new technologies is the flipped classroom where "direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject manner."[2] There have been numerous studies that have explored the potential benefits of a flipped classroom approach. For example, studies have

shown flipped classrooms may increase students' ability the focus in class[3] and increase test scores.[4-10] Flipped classroom strategies often employ active learning exercises, which Felder and Brent (2009) define as, "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes."[11] Active learning exercises have been shown to boost academic performance; Freeman et al.'s (2014) meta-analysis of 225 studies on active learning in STEM courses found that performance on concept inventories, exams, and passing rates generally improved in classrooms employing active learning strategies.[12]

A flipped classroom strategy is not guaranteed to result in improved academic outcomes. Some flipped classroom experiments show no significant gains between a section employing a flipped learning pedagogy and a section employing a traditional lecture pedagogy, or gains in some areas but losses in other areas.[13-15] Regardless of student academic performance, the studies cited above generally found that students had a favorable opinion of the flipped classroom materials and activities.[16] Despite the potential advantages of a flipped learning pedagogy, the traditional lecture style of teaching, where class time is utilized by instructors primarily for lecturing on new topics while students passively take notes, still dominates most engineering classrooms.

1.2 Prior study by the author

In a previous study, the author experimented with both a flipped classroom format (called "hybrid" in that paper) and a traditional lecture format (called "lecture-only" in that paper) in two sections of ME 232 ("Engineering Digital Computations") at Cal Poly Pomona during Spring 2014.[17] ME 232 is a 10-week introductory computer programming course for mechanical engineering students that teaches them how to program using the Visual Basic for Applications (VBA) language in Excel. In that study, the flipped section met once per week for 75 minutes while the traditional lecture section met twice per week for 50 minutes (100 minutes total). It was found that there was no statistically significant difference in student academic performance on similar quizzes and exams despite the flipped classroom students meeting for 25% less time per week, and students in the flipped classroom had a very favorable opinion about the experience.

1.3 Purpose of present study

There are two reasons why the author conducted the present study:

1) The Spring 2014 study was the author's first attempt at a flipped classroom approach and numerous small improvements were implemented in future iterations of the course, such as modifying questions used in class activities. Additionally, the sample size in the previous study was small, with only 20 and 25 students in the flipped and traditional lecture sections, respectively. The Spring 2014 experiment was repeated in Fall 2014 to test whether the results from the previous study could be improved.
2) It is possible that the reduced class time for the flipped section (75 min/week) compared to the traditional lecture section (100 min/week) in Spring 2014 and Fall 2014 hurt the academic performance of students in the flipped section. In Winter 2015 the flipped and traditional lecture sections were given an identical amount of in-class meeting time (110 min/week) to test whether the amount of in-class time would impact student performance and attitudes.

2.1 Description of flipped classroom format

The format of the flipped classroom section is described in detail in Nissenson (2015).[17] Briefly, the course content was divided into weekly modules on the university's LMS (Blackboard) with each module focused on a different topic (e.g., all activities in the Week 7 module involve loops). Students complete most activities before coming to class including:

- Watch a short video of the instructor introducing the topic, then read the week's learning objectives.
- Watch short video tutorials that discuss concepts and examples related to the week's topic. Each video is typically 5–10 min in length and the total amount of viewing time each week is 30–60 min.
- Complete an ungraded online "sanity-check quiz" to self-assess whether they understand the key concepts in the videos. Students receive feedback automatically for incorrect answers.
- Complete an ungraded online "pre-quiz" which asks students to predict the output from a VBA program. This activity prepares the students for a graded quiz in class.

After completing the above activities outside of class, students attended the lone meeting of the week in a computer lab where they performed the following tasks:

- Take a graded quiz (10 min) and discuss the solution immediately upon completion.
- The instructor discusses examples and answers students' questions related to the week's topic.
- The remaining time (30–40 min) is dedicated to "Team Battles," an active learning exercise in which students are paired randomly in teams of three and presented with three short programming problems. Students are encouraged to help their teammates during this activity and the four teams that complete the programming problems the fastest receive a prize consisting of a small amount of extra credit and candy. The prize is awarded by having a representative from each team come to the front of the room and run a program that randomly selects a prize (see Figure 1).

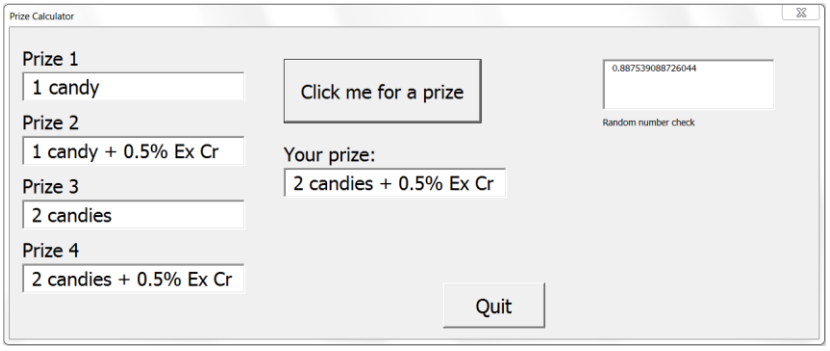

Figure 1: The random prize generator for Team Battle winners developed by the author. One representative from each winning team pushes the "Click me for a prize" button, which randomly selects one of four prizes from the left. The prize is given to each member of the team.

After class, students are given a week to complete 2–3 homework problems for each topic, which are submitted through Blackboard upon completion. The homework requires students to apply the concepts learned during the week to solve more challenging problems.

The author used Camtasia Studio, Excel, and PowerPoint to create 42 videos that cover all topics in the course. An additional 10 one-minute introductory videos for each module were created with the help of a student assistant. All videos are captioned for accessibility and available to the public as an open education resource on YouTube.[18] Further details about the process of video production can be found in Nissenson (2015).[17] The videos allow students to review content as many times as needed to understand a concept. Based on the previous study, it was found that the videos were sufficient to replace the course textbook, saving students approximately $50.

Students' grades were based on seven in-class quizzes (20% of overall grade), bi-weekly homework assignments (10%), a midterm exam (25%), final exam (30%), group project (10%), and participation in online discussion boards (5%). The average amount of extra credit earned by students from Team Battles in the flipped sections throughout the entire quarter amounted to only 0.50-0.75%, which is added to their overall course score at the end of the quarter. The author added a similar amount of extra credit to the overall course scores of the traditional lecture students when assigning letter grades at the end of the quarter to negate this small advantage.

2.2 Description of traditional lecture section

In the traditional lecture section, class time was used primarily for lecturing on new content. Students were given access to the video tutorials and pre-quizzes as supplemental resources, but were not given access to the sanity-check quizzes nor participated in Team Battles. Students' grades were based on the same criteria as the flipped section (e.g., quizzes are 20%, midterm exam is 25%, final exam is 30%, etc.). Table 1 summarizes the important differences between the two sections examined in this study.

Table 1: Comparison of the flipped classroom format and traditional lecture format

	Flipped classroom	Traditional lecture
Weekly in-class meeting time:		
Fall 2014	W 10:00-11:15am	M W 9:00-9:50am
Winter 2015	M 10:00-11:50am	M 8:00-9:50am
Access to video tutorials	✓	✓
Access to sanity-check quizzes	✓	
Access to pre-quizzes	✓	✓
Participate in Team Battles	✓	
Number of quizzes [a]	7	4

[a] All sections had four similar quizzes, as well as one similar Midterm Exam and one similar Final Exam.

2.3 Implementation of study

During both Fall 2014 and Winter 2015, the flipped section and traditional lecture section met back-to-back on the same day and were taught by the author to reduce time-of-day and instructor biases. The author had no control the placement of students in the four sections since all students at Cal Poly Pomona self-enroll long before the term begins. However, the students did not know the format of their section when enrolling in the course and only learned this educational study would be conducted on the first day of class.

Academic performance was measured through six summative assessments – four quizzes, midterm exam, and final exam – and each assessment contained similar content across all sections (i.e., all four sections had comparable quizzes, midterm exam, and final exam). Table 2 shows the deployment schedule of the assessments.

Table 2: Weekly schedule of quizzes and exams

	Week Number										
	1	2	3	4	5	6	7	8	9	10	11
Flipped section		Q1	Q2	Q3	Q4	Q5	Mid	Q6		Q7	Final
Lecture section			Q1[a]		Q3		Mid	Q6		Q7	Final

[a] Quiz 1, Quiz 3, Quiz 6, Quiz 7, Midterm Exam, and Final Exam were administered to both sections and contained comparable content. Although there were only four quizzes in the traditional lecture section, they are labeled Q1, Q3, Q6, and Q7 in the paper for comparison purposes. Due to scheduling issues, some quizzes and the Final Exam were administered on separate days.

In all sections, IRB-approved pre-course and post-course surveys were deployed through Blackboard. The pre-course survey was administered during Week 1 and obtained information on students' prior experience with computer programming and flipped courses, as well as students' baseline opinions of their major, course content, and a flipped classroom format. The post-course survey was deployed during Week 10 to measure changes in students' opinions and obtain feedback about the course. Participation in the study was optional and students were not compensated for giving their consent to participate.

3.1 Results – Comparison of prior academic performance and experience

Table 3 compares the four sections' academic performance and experience with computer programming prior to enrolling in ME 232. Among the four sections, only the Winter 2015 flipped section entered the course with a significantly higher GPA compared to the other sections. Almost all of the students were enrolled in the course for the first time. The percentage of students who were computer programming novices varied greatly among the four sections, from 37% in the Winter 2015 flipped section to 75% in the Fall 2014 flipped section. It is not clear if the pre-course differences between sections played a role in student performance throughout the course, but the author includes this information for completeness.

Table 3: Students' prior academic performance and experience with computer programming

	Lecture F2014 (n = 25)	Flipped F2014 (n = 26)	Lecture W2015 (n = 22)	Flipped W2015 (n = 21)
Prior total GPA (mean ± 1σ)	3.09 ± 0.35	2.92 ± 0.58	3.13 ± 0.21	3.52 ± 0.30 [a]
Students repeating course	1	2	0	0
	(n = 19) [b]	(n = 21)	(n = 21)	(n = 19)
Know at least one computer language	15%	10%	29% [c]	16%
Unsuccessfully tried to learn a computer language	35%	15%	29%	47%
Never tried to learn a computer language	50%	75%	43%	37%

[a] One-way ANOVA test indicates there is a statistically significant difference ($p < 0.05$) for the flipped W2015 section.
[b] Some students gave consent for their data to be used in the study but did not complete the pre-course survey, resulting in different n values.
[c] Total exceeds 100% due to rounding.

3.2 Results – Comparison of academic performance

Four quizzes, a midterm exam, and a final exam that contained comparable content were administered to all four sections. Figure 2 shows the mean and one standard deviation (1σ) scores for the six assessments. For each assessment, a one-way ANOVA test was performed to determine if there is a statistically significant difference ($p < 0.05$) between the scores of the four sections. If there is significant difference, a post-hoc Tukey HSD test is performed to determine which section(s) differed significantly.

- Quiz 1: The W2015 lecture section underperformed and differed significantly from both the F2014 lecture section and F2014 flipped section.
- Quiz 3: The W2015 flipped section outperformed and differed significantly from both the F2014 flipped section and W2015 lecture section.
- Quizzes 6 & 7: Although the W2015 flipped section had the highest mean score and the W2015 lecture section had the lowest mean score, the difference between all groups was not statistically significant.
- Midterm Exam: The W2015 lecture section underperformed and differed significantly from both the F2014 flipped section and W2015 flipped section.
- Final Exam: ANOVA yields $p = 0.0498$, indicating there is a statistically significant difference in the four sections. However, the post-hoc Tukey HSD test comparison of the W2015 flipped section with the F2014 lecture section ($p = 0.058$) and W2015 lecture section ($p = 0.088$) section yields p-values greater than the $p < 0.05$ cutoff for significance.

The mean scores of the two high-stakes assessments – midterm and final exams, totaling 55% of the course grade – were highest for the flipped sections. Additionally, the W2015 flipped section had the highest mean score on all assessments except Quiz 1. This had a significant impact on the overall course scores, as seen in Figure 3. At least 50% of the students in the flipped sections received an A- or A, while less than 20% of the students in the traditional lecture sections performed that well. The W2015 flipped section performed exceptionally well, with only one student receiving a C or lower; the author taught ME 232 numerous times prior to this study and had never observed such a high rate of As and Bs.

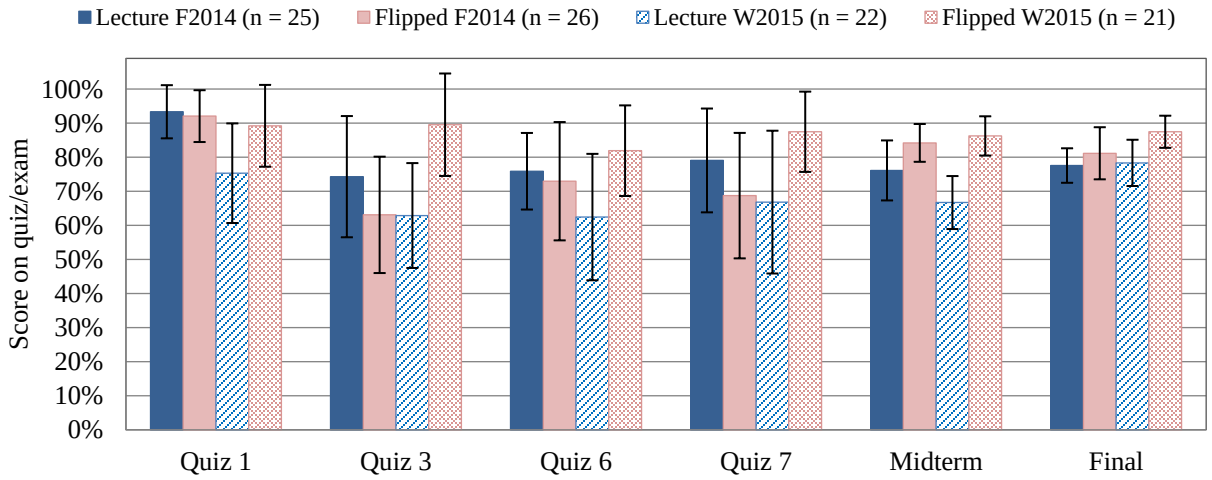

Figure 2: Student performance on similar quizzes and exams. The bar height represents mean values and the whiskers represent one standard deviation.

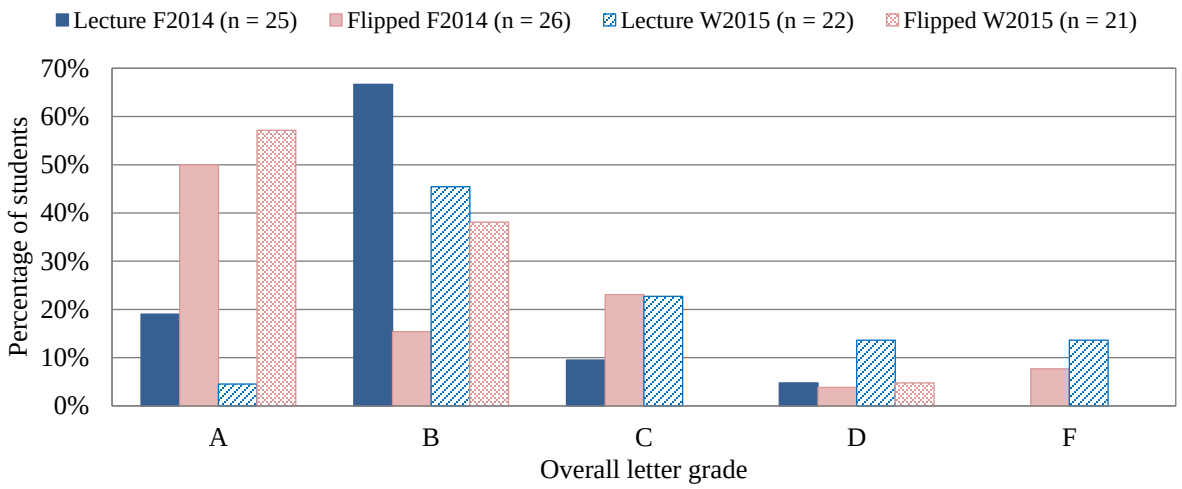

Figure 3: Overall student performance in the course. For clarity, grades have been grouped together based on letter (e.g., C-, C, and C+ grades are grouped in the "C" category). Grades were assigned using the traditional scoring system of A = 90-100%, B = 80-90%, C = 70-80%, D = 60-70%, F = below 60%. Pluses and minus were assigned for students within 2.5% of a grade range boundary (e.g., C+ was given for overall scores in the range of 77.5-80%).

The optional ungraded sanity-check quizzes were intended to help students in the flipped sections self-assess their level of understanding of the concepts in the videos. Figure 4 compares the performance of flipped section students on the final exam with the number of sanity-check quizzes attempted. There is no significant correlation between the two variables at the 95% confidence level, suggesting the sanity-check quizzes had minimal impact on student performance on the final exam. This result was also found in the previous study,[17] suggesting that the sanity-check quizzes could be omitted without impacting student learning outcomes greatly.

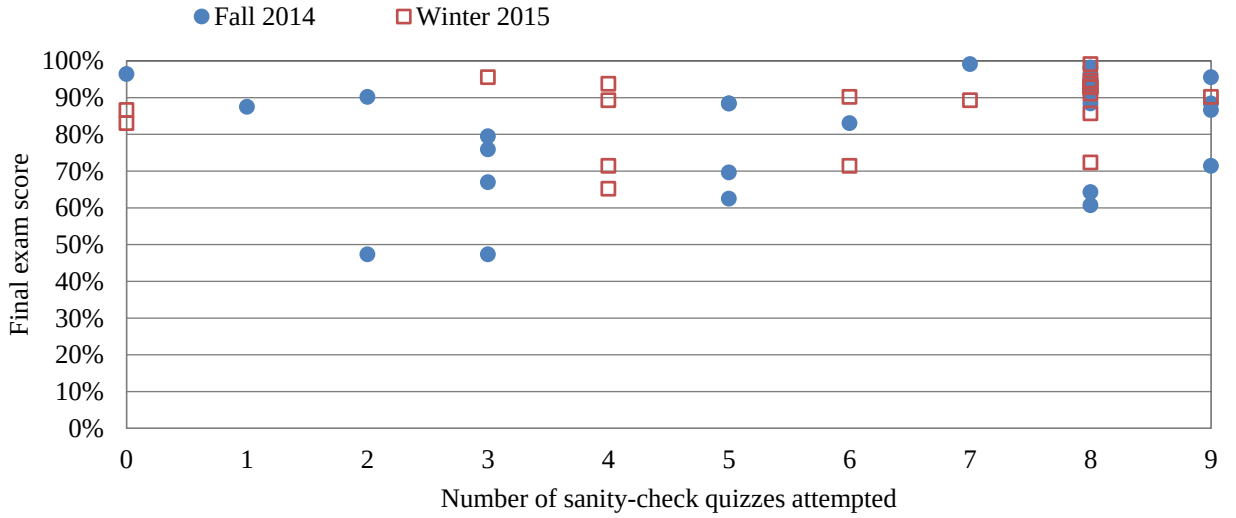

Figure 4: Comparison of final exam scores and the number of sanity-check quizzes attempted for students in the flipped sections. Each data point represents one student. There is no statistically significant relationship between the two variables at the 95% confidence level – a linear fit, logarithmic fit, and power law fit produced best-fit curves with $R^2 < 0.1$.

3.3 Results – Comparison of survey results

Pre-course (Week 1) and post-course (Week 10) surveys contained common questions that used a five-point Likert scale (1 = most unfavorable, 5 = most favorable) to measure how students' opinions on various topics changed during the course. A Wilcoxon signed rank test was used to determine if there was a statistically significant difference between the pre-course and post-course opinions at the 95% confidence level in a given section. When there was insufficient data for a Wilcoxon signed rank test, a paired Student's t-test analysis was used instead.

Table 4 shows that students in all sections saw an increase in their favorability rating of computer programming. Additionally, the flipped sections saw greater gains in their opinion of the flipped classroom format, suggesting that exposure to a flipped classroom experience can make students more likely to embrace the pedagogical style in the future. There was no significant change in the students' opinions about being an ME major, although satisfaction was already high at the beginning of the course.

Table 4: Comparison of pre-course and post-course surveys

	Lecture F2014 (n = 14) Mean ± 1σ		Flipped F2014 (n = 16) Mean ± 1σ	
	pre	post	pre	post
Opinion of programming [a]	3.86 ± 0.86	4.43 ± 0.85[†]	3.63 ± 0.81	4.25 ± 0.68[†]
Opinion of flipped courses [b]	2.85 ± 0.80	3.08 ± 0.86	3.19 ± 1.05	4.00 ± 0.97[†]
Satisfaction with major [c]	4.71 ± 0.47	4.43 ± 0.85	4.63 ± 0.50	4.63 ± 0.50
	Lecture W2015 (n = 13)		Flipped W2015 (n = 15)	
	pre	post	pre	post
Opinion of programming	3.54 ± 1.05	3.92 ± 1.44[†]	3.67 ± 0.82	3.93 ± 0.96
Opinion of flipped courses	3.46 ± 0.88	3.61 ± 0.96	3.33 ± 0.62	3.87 ± 1.30[†]
Satisfaction with major	4.54 ± 0.66	4.62 ± 0.65	4.73 ± 0.46	4.80 ± 0.41

[†] Wilcoxon signed rank test analysis indicates that the difference between the pre-course and post-course surveys is statistically significant at the 95% confidence level.

[a] "I _____ computer programming." (5) really like, (4) somewhat like, (3) neither like nor dislike, (2) somewhat dislike, (1) really dislike

[b] "I _____ flipped courses." Same five-point scale as in the previous question.

[c] "I am _____ with being a Mechanical Engineering major." (5) very satisfied, (4) somewhat satisfied, (3) neither satisfied nor dissatisfied, (2) somewhat dissatisfied, (1) very dissatisfied

Feedback about the flipped classroom format was generally positive. Table 5 shows that the flipped section students found the Team Battles effective, liked discussing the quizzes immediately after completing them, and felt the amount of in-class time per week was sufficient to learn the material.

Table 5: Results from post-course surveys on aspects of the flipped classroom format

	Flipped F2014 (n = 21)	Flipped W2015 (n = 17)
Opinion on amount of in-class time:		
• Sufficient to learn the material and should remain the same	71%	82%
• Sufficient to learn the material but should be decreased	5%	6%
• Insufficient to learn the material and should be increased	24%	12%
	Mean	Mean
Effectiveness of Team Battles [a]	4.10	4.29
Opinion of quiz solutions being discussed in class [b]	4.81	4.65

[a] "The in-class Team Battles were _____ in helping me learn the material." (5) very effective, (4) somewhat effective, (3) neither effective nor ineffective, (2) somewhat ineffective, (1) very ineffective

[b] "I _____ that we discussed the solution to a quiz immediately after taking the quiz." (5) really like, (4) somewhat like, (3) neither like nor dislike, (2) somewhat dislike, (1) really dislike

Although students in the flipped sections were required to watch the video tutorials before coming to class, the videos also were made available to the traditional lecture sections as a supplemental resource. The author did not track the viewing habits of each student, but two questions on the post-course survey probed the perceived usefulness of the videos and how they were used throughout the quarter. Table 6 shows that both the traditional lecture and flipped sections felt the video tutorials were very helpful in learning the course material.

Table 6: Perceived usefulness of video tutorials

Section	Mean rating [a]
Lecture F2014 (n = 16)	4.69
Flipped F2014 (n = 21)	4.90
Lecture W2015 (n = 14)	4.71
Flipped W2015 (n = 17)	4.76

[a] "What is your opinion of the following statement? The video tutorials were helpful in learning the course material." (5) strongly agree, (4) slightly agree, (3) neither agree nor disagree, (2) slightly disagree, (1) strongly disagree

Students in the flipped sections reported using the videos to learn new material and refresh their memory about difficult topics. Students in the traditional lecture sections reported using the videos to better understand difficult topics, seek help with homework problems, replace lecture if absent from class, and prepare before coming to class. Students particularly enjoyed being able to watch the videos as many times as needed to understand a concept, a sentiment reported in many flipped classroom studies. Below are typical quotes from students in the traditional lecture sections about their use of video tutorials:

- "*If I got stuck on a homework problem I would go back and watch the tutorials to help get the juices going*."
- "*When I was unable to attend class, the videos were very helpful and in-depth, kept me up to date with the material*."
- "*I used [the videos] to familiarize myself with new content before the class, refer back to it when doing the homework, and then watched them again when reviewing for quizzes and exams*."
- "*I watched each video that was relevant to the upcoming class prior to the class, usually an hour before class started*."

The Team Battles were a popular feature of the flipped classroom experience. Below are typical quotes from students about this active learning exercise.

- "*The Team Battles aided in collaborative learning and also aided in learning of the material as the pressure of competition was enough to help solidify the concepts while not being so great as to adversely affect the learning process due to not having a negative impact on grading and the like*."
- "*[Team Battles] were fun and the fact that we got random teammates kept them somewhat fair*."
- "*I liked being able to come to class already knowing the material and being able to use it in class to help it sink in, with the professor and students able to help out if I struggled with a Team Battle concept*."

Although most students in the flipped sections were satisfied with the course structure, some suggestions for improvement include allowing students an opportunity to ask questions in-class before quizzes are administered, giving credit for the sanity-check quizzes, increasing the amount of extra credit for Team Battle winners, and making participation in the discussion boards optional rather than mandatory.

4. Discussion and long-term impact

The results from this study demonstrate the potential benefits of using a flipped classroom format to improve student academic performance in an engineering course. Both flipped sections outperformed the traditional lecture sections on high-stakes exams and received higher overall course scores. Among the two flipped sections, the section that met 110 min/week (W2015) outperformed the section that met 75 min/week (F2014), suggesting that students in flipped classrooms benefited from the increased face-to-face time. Interestingly, among the two traditional lecture sections, the section that met twice per week for 100 min total (F2014) outperformed the section that met once per week for 110 min total (W2015), suggesting that more frequent meetings could benefit traditional lecture sections.

Possible reasons for the enhanced performance of the W2015 flipped section include:

- The flipped classroom format may be a better format than the traditional lecture format for preparing students for in-class assessments.
- W2015 was the author's third time teaching the flipped format and minor issues from F2014 and S2014 were remedied.
- There may have been an unequal distribution of academic abilities across the four sections since students self-enrolled long before the start of the quarter. As shown in Table 3, the W2015 flipped section had the highest incoming GPA and the lowest rate of students who never attempted to learn a computer language prior to the course.
- The sample size of this study is not large. However, since the completion of the study the author has taught four more sections of ME 232 using the W2015 flipped format and found similar high overall course scores.
- Students in the flipped sections had access to sanity-check quizzes and Team Battle problems, while the traditional lecture sections did not. Figure 4 shows that there is no relationship between sanity-check quizzes on final exam scores, suggesting the sanity-check quizzes had

minimal impact on academic performance. However, it is possible that the Team Battle activity played a significant role in the enhanced performance of flipped sections in this study.

Based on the success of this project, a similar flipped classroom strategy was used by the author to flip a fluid mechanics course in 2016-2017 with great success.[4,19] It should be noted that the Team Battle activity seemed to be the most popular aspect of the flipped classroom format both in ME 232 and the in fluid mechanics course, and this activity has recently been adopted by another instructor in the author's department.

Although this study demonstrates the potential benefits of a flipped classroom approach, the author notes there can be significant challenges to utilizing the same pedagogical style discussed in this paper:

- It can take a lot of time to develop a complete set of video tutorials for a course. The author estimates that a typical 5-minute video took approximately 5-10 hours of preparation, recording, editing, and captioning.
- The sanity-check quizzes, in-class quizzes, and Team Battle problem statements also took a lot of time to develop and refine.
- The instructor must be comfortable with the idea of yielding control to the students during large portions of the class time. During the Team Battles, the author wandered about the room to ensure students stayed on task and made himself available if students had questions.
- Since it is possible that the instructor's implementation of a flipped classroom may not work, the instructor should be in a position where failure is okay. When the author first attempted a flipped classroom approach in Spring 2014, there was no guarantee that students would react favorably to such a different style of teaching. However, even though the author was an untenured Assistant Professor during Spring 2014, he felt safe to perform this experiment since he discussed the study with his department Chair who gave her approval.

The impact of the videos developed for ME 232 extend well beyond the two sections examined in Nissenson (2015) and the four sections examined in this study. At Cal Poly Pomona, ME 232 is often taught by part-time lecturers who are experienced programmers but do not have a lot of experience with Excel VBA. The videos have been a valuable resource to help new lecturers get acquainted with the language quickly, ensure a consistent curriculum, and provide students with an alternative explanation of concepts. However, perhaps the videos' greatest impact is also the most difficult to quantify. All videos are available to the public as an open educational resource on the Cal Poly Pomona Mechanical Engineering Department's YouTube channel,[18] and are organized on the department's video tutorial website, ME Online (www.cpp.edu/meonline).[20] At the time of writing, the videos have accumulated over 925,000 views and over 3.3 million minutes of viewing by people around the world. Additionally, the videos were repurposed to develop Cal Poly Pomona's first massive open online course (MOOC) in 2014 and 2015,[21,22] which is now available as a free self-paced course for learning Excel VBA[23] – many tens of thousands of people have enrolled in the course since 2015. It is hoped that the videos will continue to be a valuable resource for students at Cal Poly Pomona and beyond for years to come.

5. Acknowledgments

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6. References

[1] TechSmith's Camtasia Studio software website. Accessed January 2019.
Available at: < https://www.techsmith.com/video-editor.html >

[2] Definition of flipped learning from the Flipped Learning Network website. Accessed January 2019.
Available at: < http://flippedlearning.org/Page/1 >

[3] D. Bunce, E. Flens, and K. Neiles (2010). How long can students pay attention in class? A study of student attention decline using clickers, *Journal of Chemical Education*, 87, 1438-1443.

[4] F. L. Wachs, J. L. Fuqua, P. M. Nissenson, A. C. Shih, M. P. Ramirez, L. Q. DaSilva, N. Nguyen, C. Romero (2018). Successfully flipping a fluid mechanics course using video tutorials and active learning strategies: Implementation and Assessment, in *Proceedings of the 2018 American Society for Engineering Education Annual Conference & Exposition*, Salt Lake City, UT, USA, June 24-27, 2018.

[5] A. Kaw and S. Garapati (2010). Development of Digital Audiovisual Lectures for an Engineering Course: A YouTube Experience, in *Proceedings of the 2010 American Society for Engineering Education Southeast Section Conference*, Blacksburg, VA, USA, April 18-20, 2010.

[6] S. Zappe, R. Leicht, J. Messner, T. Litzinger, H. Lee (2009). "Flipping" the classroom to explore active learning in a large undergraduate course, in *Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition*, Austin, TX, USA, June 14-17, 2009.

[7] J. Foertsch, G. Moses, J. Strikwerda and M. Litzkow (2002). Reversing the Lecture/Homework Paradigm Using eTEACH Web-based Streaming Video Software, *Journal of Engineering Education*, 91, 267-274.

[8] N. Lape, R. Levy, D. Yong, K. Haushalter, R. Eddy and N. Hankel (2014). Probing the inverted classroom: A controlled study of teaching and learning outcomes in undergraduate engineering and mathematics, in *Proceedings of the 2014 American Society for Engineering Education Annual Conference & Exposition*, Indianapolis, IN, USA, June 15-18, 2014.

[9] G. S. Mason, T. Rutar Shuman and K. E. Cook (2013). Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper-Division Engineering Course, *IEEE Transactions on Education*, 56, 430-435.

[10] D. Webster, D. Majerich, and A. Madden (2016). Flippin' fluid mechanics – Comparison using two groups, *Advances in Engineering Education*, 5, 1-20.

[11] R. M. Felder and R. Brent (2009). Active learning: An introduction, *ASQ Higher Education Brief*, 2(4).

[12] S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt, and M. P. Wenderoth (2014). Active learning increases student performance in science, engineering, and mathematics, in *Proceedings of the National Academy of Sciences*, 111, 8410-8415.

[13] J. Thomas and T. Philpot (2012). An inverted teaching model for a mechanics of materials course, in *Proceedings of the 2012 American Society for Engineering Education Annual Conference & Exposition*, San Antonio, TX, USA, June 10-13, 2012.

[14] M. Redekopp and G. Ragusa (2013). Evaluating Flipped Classroom Strategies and Tools for Computer Engineering, in *Proceedings of the 2013 American Society for Engineering Education Annual Conference & Exposition*, Atlanta, GA, USA, June 23-26, 2013.

[15] C. McClelland (2013). Flipping a large-enrollment fluid mechanics course: Is it effective? in *Proceedings of the 2013 American Society for Engineering Education Annual Conference & Exposition*, Atlanta, GA, USA, June 23-26, 2013.

[16] Bishop, J. and M. Verleger (2013). The flipped classroom: A survey of the research, in *Proceedings of the 2013 American Society for Engineering Education Annual Conference & Exposition*, Atlanta, GA, USA, June 23-26, 2013.

[17] P. M. Nissenson (2015). Impact of a hybrid format on student performance and perceptions in an introductory computer programming course, in *Proceedings of the 2015 American Society for Engineering Education Pacific Southwest Conference*, San Diego, CA, USA, April 9-11, 2015.

[18] Playlist of video tutorials used in ME 232.
Available at: < http://www.youtube.com/playlist?list=PLZOZfX_TaWAGg2uE_E7fz5SCrHhMaKw8j >
(Note: The course name changed from ME 232 to ME 1101/L in Fall 2018.)
[19] P. M. Nissenson, F. L. Wachs, J. L. Fuqua, Y. Zhao, S. Pedroza, A. C. Shih (2017). Impact of an Online Learning Environment on Student Performance and Perceptions in a Fluid Mechanics Course, in *Proceedings of the 2017 American Society for Engineering Education Annual Conference & Exposition*, Columbus, OH, USA, June 25-28, 2017.

[20] Cal Poly Pomona Mechanical Engineering Department's video content website, ME Online.
Available at: < http://www.cpp.edu/meonline >

[21] P. M. Nissenson and A. C. Shih (2015). MOOC on a budget: Development and implementation of a low-cost MOOC at a state university, in *Proceedings of the 2015 American Society for Engineering Education Annual Conference and Exposition*, Seattle, WA, USA, June 14-17, 2015.

[22] P. M. Nissenson and T. D. Coburn (2016). Scaling-up a MOOC at a State University in a Cost-effective Manner, in *Proceedings of the 2016 American Society for Engineering Education Annual Conference & Exposition*, New Orleans, LA, USA, June 26-29, 2016.

[23] Free self-paced online course titled, "Introduction to Excel VBA Programming."
Available at: < https://openeducation.blackboard.com/mooc-catalog/courseDetails/view?course_id=_219_1 >