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Effectiveness Of Flipping The Classroom In A Honors Level, Mechanics-Based Physics Class

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The Effectiveness of Flipping the Classroom in a Honors Level, Mechanics-Based Physics Class

BY

Stephen J. Zownorega

THESIS

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CHARLESTON, ILLINOIS

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Abstract.

The idea behind "flipping the classroom" is that standard lecture can be sent home with students to view and take notes. Class time that had traditionally been used for presenting lecture information can then be used by the teacher for different teaching methods in class. These teaching methods support what was seen in a video (i.e., screencast) and allows students an opportunity to develop a better understanding of the concepts viewed the night before. During class time the teacher can work individually with students, thus increasing personal contact time between teacher and student. Videos also allow students to access lecture material and sample problems wherever and whenever they want providing different opportunities for review and to improve understanding. Flipping the classroom should allow students to use class time more efficiently and improve their results on assessments used in class. Using this method, students should have more time for problem solving in groups and teachers are able to use the Socratic questioning method to help students develop different problem solving techniques. Laboratory activities and simulations were also designed to help students better visualize and actively engage in course material. In this study a full-fledged modeling methodology was implemented rather than the partial modeling methodology used in previous studies. It evaluated the 2011-2012 academic year using the traditional model (all information presented in class) and the 2012-2013 academic year using the flipped model. The same unit tests were used to compare these two years of different teaching models. To better understand of the overall affect, the flipped model was compared to several years of the Force Concept Inventory (FCI) assessment, a national test used in modeling methodology.

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Thank you all for always lending an ear and giving me your input as the school year went on.

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Introduction and Literature Review

What is the Flipped Classroom?

In 2007, Jonathan Bergman and Aaron Sams, who were teaching at a high school in Colorado, recognized that student absences led to students who were missing key concepts presented in class. In order to deliver these students the material, Bergman and Sams created videos of class lectures. The videos were subsequently made available to other students in class who wanted to re-watch lectures and review the material. This sparked an idea; why not have all students watch the videos at home and use class time to reinforce the material that has been learned? (Talbert, 2012)

The flipped model takes the traditional model of teaching; presenting information in a lecture format during class, while reinforcing the information at home through worksheets, and flips the location at where these occur. Under the flipped model, students watch lecture videos at home and get an opportunity to enhance their learning in the classroom with other students. (Udell, 2005)

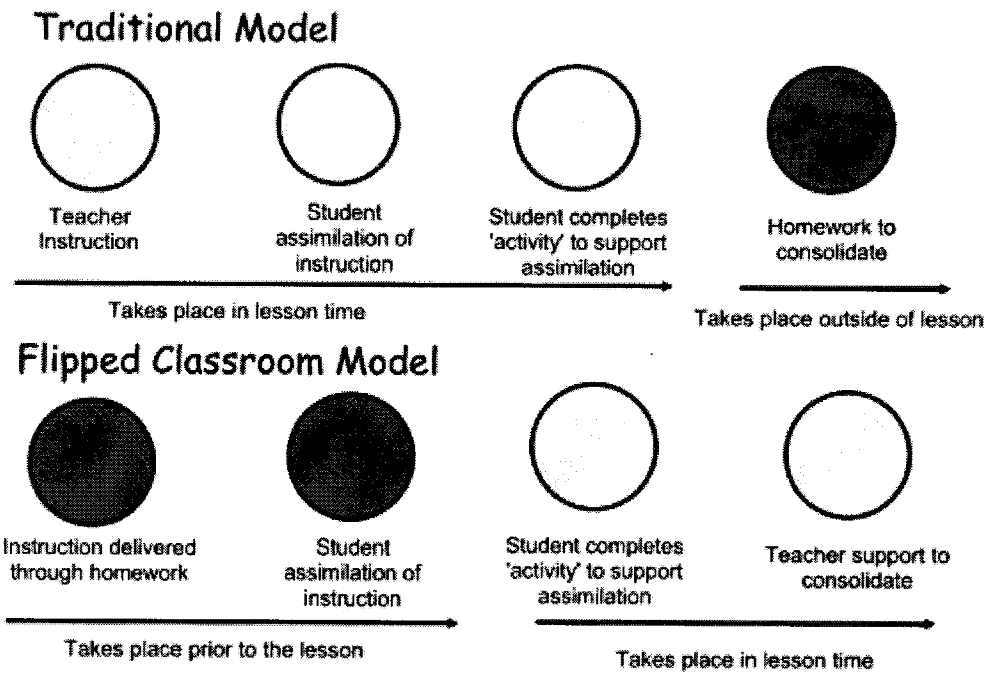

Figure 1. A comparison between the traditional and flipped classroom models (Moraevec, 2010)

A side-by-side comparison between teaching models (Fig. 1) demonstrates why this methodology is called a flipped classroom. The structure of the course stays the same, but under the flipped model, students get the lecture information at home (red). The support material, which is always seen as the secondary piece in the learning cycle, is done in class (yellow).

There are several positive aspects to a flipped classroom. First, time that is usually spent presenting information in class can now, under the flipped model, be replaced with techniques that reinforce the subject matter. (Gannod et al., 2008) Second, content being accessed at home can be reviewed as many times as needed. If a student wants to view a video explaining how to use Newton's 2nd law, they can watch it for a second or third time, if needed. With the traditional model, a student only gets one opportunity to see and hear their teacher go through the lecture material and sample problems. In addition, the content is accessible 24 hours a day, 7 days a week. With the flipped method, a student can refresh their memory before a unit exam or at any moment in the educational experience.

Two concerns expressed about the flipped method include: 1) What if a student doesn't access the material at home? How does that student respond in class to the material being reinforced?; and, 2) what if a student has a question while reviewing the video at home? How does he or she get their question answered?

The first implementation of video content to educate high school students came from the University of Northern Colorado in what was called a flipped classroom. (Talbert, 2012). Instead of a traditional classroom lecture, students were expected to watch videos lectures at home and do their problem solving in class; a flip of what the traditional physics class looks like. This technique has branched out into Apple's iTunes U where colleges use podcasts as the source of information. The Massachusetts Institute of Technology (MIT) has videos where professors teach on blackboard and students get all of the content through videos (Boutell and Clifton, 2010). SmartPhysics, a video based lecture system created by University of Illinois professors, gives students a way to access lectures and resources in a video format. Teaching Assistants then hold group problem solving sessions in lieu of lectures. (Ellington and Hardin, 2008)

One of the few quantitative studies (Gannod et al., 2008 and Kaner, 2005) completed, found that these techniques resulted in an increase in attendance and an overall increase in the number of students who pass these classes. Most other studies reflected on how students have better questioning techniques, more thoughtful discussions, and an enthusiasm towards the subject (Kaner, 2005). One of the biggest downfalls in the research of the flipped classroom is how few research studies were completed on online learning in K-12 students. Between 1994 and 2006 there were no experimental or controlled experiments on the effects of online learning versus face to face instruction. In 2006, however, the U.S. Department of Education determined that there was no significant improvement in learning outcomes when online learning was used (Means et all, 2010).

Online buzz regarding education outside of academic universities has gotten the support of Microsoft, Salman Khan and the Khan Academy. The purpose of the Khan academy is to give anyone who wants to become a student a way to access information they are looking to understand. Students can view instructional videos as many times as needed with the ability to review and see sample problems as they would be done in class but on a computer screen. This has intrigued Microsoft enough to advertise to the public that anyone can educate themselves online and to supply Khan and his team with compensation to create the content. Noschese, a modeling methodology guru and advocate for modeling instruction, suggests that inquiry is the best method for students to learn:

> *"We should be inspiring [students] to figure things out on their own and learn how to create their own knowledge by working together. For example, instead of relying on lectures and textbooks, the Modeling Instruction paradigm emphasizes active student construction of conceptual and mathematical models in an interactive learning environment".*

This concept bridges some of the differences between the Khan Academy and how the flipped classroom model can be utilized to give students an opportunity to experience the classroom while still getting the information within a screencast (Nochese, 2011).

The modeling methodology is a method used in science education to give students the ability to explore concepts through questioning and exploring, a style of inquiry based science. Students are given a problem in lab and must create a model to figure out the mathematical and graphical implications. From there, they make generalizations about mathematical and graphical models to solve similar problems. At the core of modeling methodology are problem solving sessions (i.e., whiteboarding sessions) where students sit in groups and discuss how their laboratory model could be applied to a homework problem. As they solve the problem, students are taught to ask questions and find answers using evidence based reasoning. Their solutions are presented to their classmates who question their work until a final answer can be agreed upon. Through group discussions and Socratic questioning, students learn as a scientist (Wellset al., 1995. The application of the modeling method has resulted in large increases with the Force Concept Inventory (FCI) assessment. Wells et al.'s (1995 study showed a growth of more than 20% in achievement using the modeling method rather than the traditional method of teaching physics.

In this proposed study, implementation of the flipped classroom and usage of class time will be assessed by in student achievement. This study will also test to see how a "modeling" classroom is affected when the classroom is also flipped . The effectiveness of student performance on assessments of lecture material and sample problems will also be evaluated. Finally, data will be gathered on how students respond to the content being delivered.

Methodology

To examine how student achievement is affected, this proposed study will consist of an experimental group of 105 students (from the 2012-2013 school year) who will access most informational pieces presented through YouTube clips that can be found on www.youtube.com/dgsphysics400/ . These students will take the exact same unit tests as a control group of about 80 students from the 2011-2012 school year. The other assessment that will be used to test the student's improvement will be the Force Concept Inventory (FCI), a well-known assessment that tests student misconceptions in physics. Both classes utilized the modeling method and the amount of time on each unit was kept the same. The only difference will be what occurred in the classroom.

Camtasia was used to record the computer screen and audio on a tablet PC during lectures and Microsoft OneNote was used to generate a large white canvas that can be written on, scrolled through, and zoomed into and out of. Lectures and sample problems were recorded as they were discussed and written down on OneNote. After the lectures were recorded they were posted on YouTube for student access. Students were given up to two days to watch the lecture. At the end of each video, students were given the opportunity to assess their understanding by answering several questions about the topic. Answers to questions were checked the following day with points assigned in class to ensure students were watching the videos. Students who did not watch the video did not receive points until they showed their notes at a later date. (Betty, 2008)

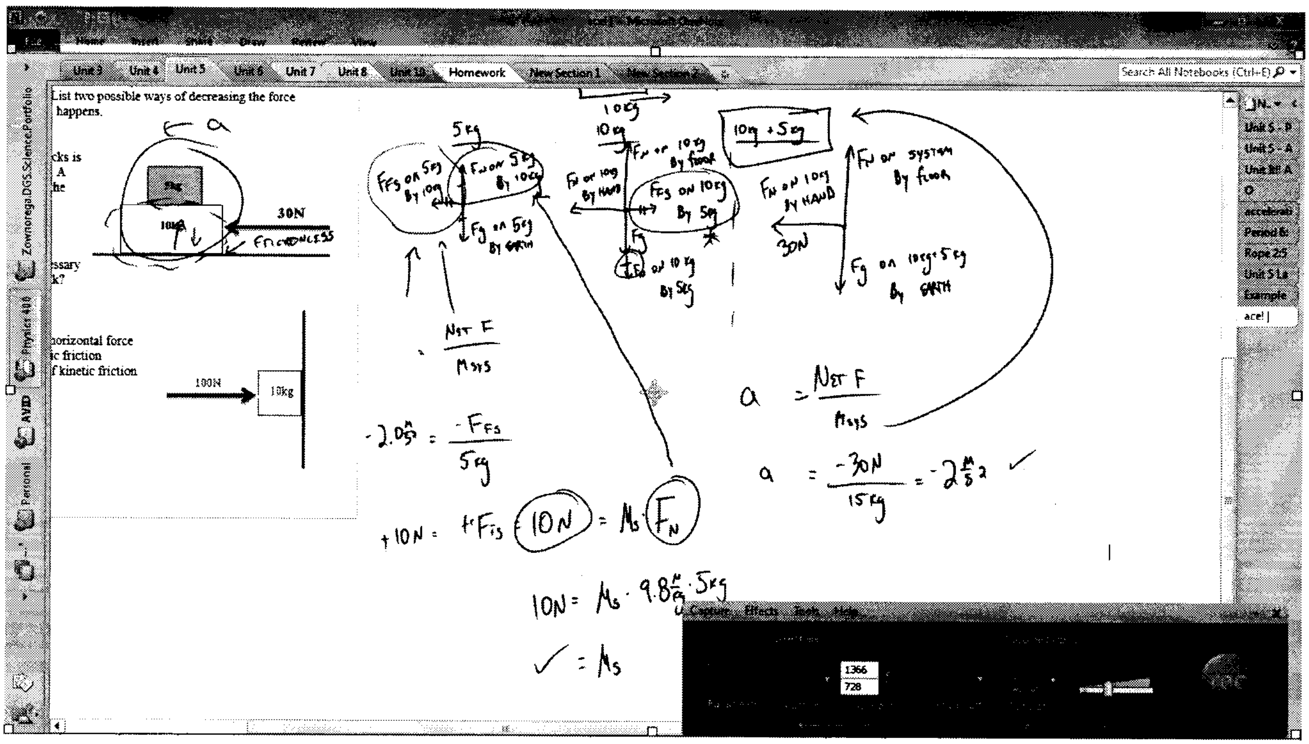

Figure 2. Sample problem screencasted with Camtasia software. Note connections made within the problem shown by the arrows drawn.

When students came to class after watching the video they were given an opportunity to ask the teacher any questions they had during the screencast. After all questions were answered and any clarification statements needed to be made, students had time to start their problem sets in class. Students worked in groups to solve up to 7 problems and were allowed to ask questions in their group, of other people in the class, or the instructor. This allowed more time for the modeling method to be implemented to its fullest capability. Students who did not watch the video were required to participate in these discussions to the best of their ability.

Time Frame	**Tradition Model**	**Flipped Model**
Before Class Homework	None	Watch the video (5-10 minute lecture)
1st Day	**Lecture – *30-40 minutes*** Usually includes a post lab discussion and a sample problem that allows students to see how to use the material. Very little questioning occurred during this time while students were busy processing material	**Clarifications of Lecture – *5-10 minutes*** Students had a time to process the material after they watched the lecture the night before and ask questions based upon the sample problem they tried in the video. High level questions were asked based upon the application.
Rest of Period/Group Work Time	**Start Worksheet in Class – *10 minutes*** Students have a moment to look at problem 1 before going home. Problem 1 usually dealt with a reoccurring topic, or a simple plug and chug situation.	**Start Worksheet in Class in groups – *40 minutes*** Students used this time to go through the first 4-5 problems. Many questions that would normally cause a student to struggle and not finish a problem was asked to their group members and most students completed these problems
1st Day – Homework	1st attempts done for next class period	All problems attempted/completed for the next class.
Day 2	**Continue to Work in Groups** Students use this time to process material from day before	**Finish Group Work/Present Problems** Students use this time to finish their discussions and get their group prepared to present their solutions to the problems
Day 3	**Present Problems**	**Extra Time Gained**

Figure 3. Breakdown of traditional method of teaching for 2011-2012 school year versus the flipped method of teaching in the 2012-2013 school year.

Based on the breakdown of the two models, the flipped model often allows for students to have an extra day of class before the unit test. This extra day was used in two different ways; 1) allowing students an extra day to work in groups on the worksheets; and, 2) on Colorado University's website PHet simulations.

Three methods of assessment were used to compare the 2011-2012 traditional model against the 2012-2013 flipped model.

1. Unit Tests

Unit tests were used to get an understanding of the learning expectations for the students. Questions are conceptually based and test students not on numerical problem solving but conceptual skills

2. Final Exam

Questions were problem solving based. Most answers deal with a final answer that is numerical. This test has been used in the district for the past 5 years and can be compared to prior years to get a better understanding of student problem solving capabilities.

3. Force Concept Inventory (FCI)

This test is a nationally recognized test that is conceptual in nature. It specifically targets student understanding of concepts and student misconceptions. While students assess that they scored within the 50%-60% range on a pretest, their scores actually average out to be 26%, slightly above if the students were guessing on each question.

An analysis of each item included the percentage answered correctly (Fig 4, in green). Item analysis was examined for 3 honors classes taught using the traditional method (2011-2012 school year) and 4 honors classes using the flipped method (2012-2013 school year). Data points were used to compare the traditional method to the flipped method.

Item	A	B	C	D	E	Multi Mark	Omit	Diff.	Discr.	r_{pb}
101	2 2%	3 3%	**100 94%**	1 1%	0 0%	0 0.00%	0 0.00%	0.94	0.03	0.07
102	**66 62%**	21 20%	2 2%	16 15%	0 0%	0 0.00%	1 0.94%	0.62	0.38	0.34
103	6 6%	14 13%	**80 75%**	3 3%	3 3%	0 0.00%	0 0.00%	0.75	0.38	0.39
104	9 8%	0 0%	0 0%	0 0%	**97 92%**	0 0.00%	0 0.00%	0.92	0.17	0.25
105	31 29%	**45 42%**	18 17%	6 6%	6 6%	0 0.00%	0 0.00%	0.42	0.52	0.40
106	11 10%	**92 87%**	1 1%	2 2%	0 0%	0 0.00%	0 0.00%	0.87	0.28	0.34
107	5 5%	**97 92%**	3 3%	0 0%	1 1%	0 0.00%	0 0.00%	0.92	0.28	0.33
108	31 29%	**68 64%**	0 0%	2 2%	5 5%	0 0.00%	0 0.00%	0.64	0.48	0.36
109	3 3%	26 25%	21 20%	10 9%	**46 43%**	0 0.00%	0 0.00%	0.43	0.66	0.50
110	**100 94%**	2 2%	2 2%	2 2%	0 0%	0 0.00%	0 0.00%	0.94	0.17	0.37
111	4 4%	1 1%	7 7%	**90 85%**	4 4%	0 0.00%	0 0.00%	0.85	0.31	0.37
112	2 2%	**81 76%**	20 19%	1 1%	2 2%	0 0.00%	0 0.00%	0.76	0.55	0.50
113	0 0%	10 9%	15 14%	**80 75%**	0 0%	0 0.00%	1 0.94%	0.75	0.48	0.48
114	8 8%	24 23%	11 10%	**62 58%**	1 1%	0 0.00%	0 0.00%	0.58	0.66	0.51
115	**71 67%**	2 2%	32 30%	1 1%	0 0%	0 0.00%	0 0.00%	0.67	0.21	0.18
116	**100 94%**	0 0%	4 4%	0 0%	2 2%	0 0.00%	0 0.00%	0.94	0.14	0.24
117	29 27%	**72 68%**	1 1%	3 3%	1 1%	0 0.00%	0 0.00%	0.68	0.41	0.30
118	2 2%	**89 84%**	6 6%	7 7%	2 2%	0 0.00%	0 0.00%	0.84	0.31	0.37
119	30 28%	1 1%	1 1%	5 5%	**69 65%**	0 0.00%	0 0.00%	0.65	0.28	0.25
120	9 8%	2 2%	14 13%	**79 75%**	2 2%	0 0.00%	0 0.00%	0.75	0.59	0.55
121	2 2%	21 20%	39 37%	9 8%	**35 33%**	0 0.00%	0 0.00%	0.33	0.45	0.41
122	40 38%	**47 44%**	3 3%	16 15%	0 0%	0 0.00%	0 0.00%	0.44	0.41	0.38
123	12 11%	**53 50%**	27 25%	9 8%	5 5%	0 0.00%	0 0.00%	0.50	0.66	0.48
124	**91 86%**	2 2%	9 8%	0 0%	4 4%	0 0.00%	0 0.00%	0.86	0.31	0.42
125	4 4%	2 2%	**53 50%**	44 42%	3 3%	0 0.00%	0 0.00%	0.50	0.66	0.49
126	46 43%	13 12%	1 1%	14 13%	**32 30%**	0 0.00%	0 0.00%	0.30	0.69	0.57
127	24 23%	13 12%	**65 61%**	4 4%	0 0%	0 0.00%	0 0.00%	0.61	0.66	0.54
128	2 2%	1 1%	0 0%	10 9%	**91 86%**	0 0.00%	2 1.89%	0.86	0.24	0.28
129	1 1%	**102 96%**	0 0%	1 1%	0 0%	0 0.00%	2 1.89%	0.96	0.03	0.08
130	32 30%	5 5%	**54 51%**	1 1%	12 11%	0 0.00%	2 1.89%	0.51	0.62	0.50
Mean:	20.82 / 69%									
Median:	21.00 / 70%									
Variance:	23.52									
Standard Deviation:	4.85									
Standard Error:	0.47									

Figure 4. Item analysis for the FCI posttest. Data was collected using the mastery manager program at Downers Grove South High School. The program provides an electronic way of recording multiple choice results for assessments.

The number of multiple choice questions assessed was designed to create as many data points as possible (Fig. 5). Each class had N students that took 154 multiple choice questions within the mechanics units.

	Traditional Model	Flipped Classroom Model
Number of Students	82	105
Number of Questions on: Unit Tests 1st Semester Final Exam FCI	 104 20 30	 104 20 30
Total Number of Questions Used in study	154	154
Possible Data Points Taken	12628*	16170*
Actual Data Points Taken	12421	15921

Figure 5. Numerical breakdowns of unit tests, number of students taught in each model, and the number of multiple choice questions used in the comparison. *The number of possible and actual data points are different due to some students missing tests/not being registered within the mastery manager dataset.

Data points were analyzed by comparing percentages from the traditional method to the flipped method. A difference calculation (flipped method % correct – traditional method % correct) between each multiple choice question was prepared and an average percent difference was computed after analyzing the results. Unit tests include 3 sets of categories with specific understanding that is being assessed in the students. Unit tests are the best determination of how student knowledge improved since the questions are directly related to things students learn in class. The 1st semester final exam is a district test that has been used in the honors physics curriculum for the last 5 years. Data is used to assess a student's problem solving skills and can be compared to other district teacher's results. The FCI is specifically designed to test student misconceptions and is the tool with the best credibility within the physics community.

Results

In order to make the best analysis, the percentages of students who achieved the correct response was recorded for all multiple choice questions (Fig. 6) . A comparison between methodologies was determined by subtracting the flipped method percent and from the traditional method percent. A positive value suggests growth from the traditional to flipped method, and a negative value suggests a lack of growth using the flipped method.

Test	Difference in Percent of Students Who Answered the Questions Correctly	Number of MC Questions	95% Confidence
All Unit Tests	-1.25%	104	+/-0.2%
Final Exam	2.60%	20	+/-1.1%
FCI Post Test	-0.70%	30	+/- 0.6%

Figure 6. Difference in percentages between the flipped and the traditional method on the same multiple choice questions within different assessments

A second comparison was run through FCI scores in the last 5 years (Fig. 7). The FCI tests students on concepts around force and specifically tackles common misconceptions that students unearth.

School Year	PRE Score	POST Score	DIFFERENCE in Pre and Post
2008-2009	7.91	17.07	8.75
2009-2010	7.77	19.11	11.35
2010-2011	8.24	21.34	13.10
2011-2012	8.38	21.35	12.97
Flipped Classroom (2012-2013)	8.39	20.81	12.42

Figure 7. FCI results of an honors physics class comparing the average scores of students of the pretest and posttest. The test has 30 questions.

A third comparison to consider is how students performed on the final exam within the last 5 years (Fig. 8).The final exam tests student ability to problem solve. Many of the questions have a physics concept that involves a calculation or two that have to be performed in order to get the correct answer. The final exam is out of 20 questions and covers all of mechanics except energy and momentum.

School Year	Average Class Score	District Average
2008-2009	16.0	13.3
2009-2010	15.6	14.5
2010-2011	15.9	15.1
2011-2012	15.2	14.4
2012-2013 (Flipped Model)	15.8	14.7

Figure 8. Results of final exam data within the last five years of teaching. District averages include different teachers with different teaching styles at Downers Grove South and Downers Grove North.

Finally, the students took a survey after completing the course using the flipped model (Fig. 9). Using a Likert scale (1 being negative and 4 being positive), students were asked to reflect on their experience with the flipped classroom and provide comments about their experience with the learning material.

Question	Average Score (out of 4)
How has the flipped classroom helped you as a student?	3.6
Did the videos help you study for the tests?	3.3
Were the classroom activities helpful for you to better understand the material after watching the video?	3.9
In comparison to the standard model of learning (prior science classes), rate your experience with the flipped classroom.	3.7

Figure 9. Results of survey of students in the flipped classroom. Scale was out of 4 and 98 students took the survey.

Discussion

The difference in percent for the unit test scores was -1.25% +/- 0.2% within a 95% confidence interval (Fig. 6). This implies that the difference between the traditional and flipped method was 1.05%-1.45% per question better with the traditional method of teaching. As a result, the flipped classroom didn't show any growth and, in fact, the data suggests that students performed worse under the flipped model. The final exam revealed very small growth (2.6% +/- 1.1%) and the FCI showed no growth (-0.7%+/- 0.6%).

The 2012-2013 FCI average (Fig. 7) was equivalent to the 2011-2012 and 2010-2011 results, which suggests that students came in with the same amount of knowledge (similar pre-test scores) and similar backgrounds in physics. The flipped model showed a slight decrease in growth (0.5 points) and thus it can be concluded that there was no significant change with the flipped model.

A long range study of final exam data (Fig. 8) shows that students were consistently within a 4% margin within the last 5 years. The flipped model yielded results that were similar to the last 2-3 years of data. As such, there are insignificant changes among students within the last 5 years of the final exam.

Although the delivery of the material was different, the results were the same. Whether students spend their time reading a book, looking over notes or watching a screencast, there are students who will get the material and those who will not. Those who are willing to spend the extra time to watch a video or take on extra challenges are those who will improve. Successful students performed well under the traditional or flipped model. The flipped method was used with a group of students who found the information that they were expecting and processed it with the resources at hand. These students are going to get a grade on the test based on the amount of effort they put it. Although the screencasts are accessible to all, it only benefits those who are willing to use the material, much the same as if students were to get this information from class or a book.

In this study, extra time in the classroom was spent solving problems and creating group dialogue about physics problems. This allowed many students to generate questions, get answers, and feel good about the physics problems they were solving. This proved to be motivational to many students and caused less frustration within a school year but may cause false confidence in their ability to answer physics questions. Extra class time generated great questions from some students in the problem solving sessions, but this might have benefited students who would have normally done well in a traditional lecture class. Students who set the bar high will achieve those results, while those who don't put in any more time will not have the same results. Most students felt favorably about spending an entire year in the flipped classroom. The average score of 90% is well within the range of being a very positive experience. Even if students were achieving at the same level as years past, is making the classroom a positive environment worthwhile?

Conclusions

This study resulted in two takeaway lessons:

1. Students performed at the same level with the flipped model and the traditional model
2. Students had a better experience with the flipped model.

Since student's performance stayed the same, a few variables that could have been a factor should be considered. As this was the first time that screencasts were created, there is a lot of room for changing variables; specifically screencasts and the quality of what students are watching. There should be changes to the types of sample problems that are screencast, the amount of videos that are accessible, and the requirements of students on watching screencasts. A second thing to consider is how class time was spent in this study. Most of the time, students were able to discuss their homework with help of their peers and instructor, very similar to the modeling methodology used in the traditional method. However, using this time differently could cause different results in future studies.

Possible changes in the study would be to include more sample problems for students to follow. In the survey, students mentioned that their best experiences were watching video clips that showed how a problem was solved. A second aspect that could be considered is the type of content that is delivered. More videos on demonstrations, laboratory activities, and videos on student whiteboarding sessions could have been used.

In conclusion, it seems that no matter what type of interventions or strategies teachers are using, we are experiencing similar results. In the future, we might add different content (more sample problems or demonstration videos) so that struggling students have access. The level of achievement that a student experiences is directly related to their time practicing the material. No matter how the material is presented, students still need to take the time to study to be successful. It doesn't matter what medium is used. A student who decides to look through their notes will be successful and that is the same success as a student who decides to rewatch a video.

It is worth noting that new ideas, such as flipping the classroom, are improving the atmosphere in the classroom. Cooperative groups, discussions, inquiry, technology, and other practices instructors are using increase the positive atmosphere within the learning environment. This can result in more students being motivated which in turn could cause more students to be more active in their search for knowledge.

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