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An Investigation of the Impact of a Flipped Classroom Instructional Approach on High School Students' Content Knowledge and Attitude Toward the Learning Environment.

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ABSTRACT

The idea of the "flipped classroom" has become increasingly popular in education. However, very little research in how "flipped classrooms" impact high school students' ability to perform on exams has been done. The purpose of this research is to add to the body of knowledge and help provide data to investigate how well students learn physics content by using the flipped classroom in a high school Physics with Technology class. Seven periods of Physics with Technology at Lone Peak High School in Highland, UT were used in this study. Three of the classes were randomly assigned to be "flipped" while the other four were taught using what is considered a "traditional" method of instruction of physics (guided inquiry). The pacing and content was matched each day and all classes participated in the same labs, homework, quizzes and tests. The defining difference is the method which the content was covered. The flipped classes watched video lectures at home to learn the majority of the content, then did what is traditionally known as "homework" in class with the teacher present to help. In this study, it was found that there was no statistically or practically significant difference in mean test scores for the first three units. Student responses on a survey also showed very little statistical difference in the students' attitudes towards the classroom environment in either instructional method.

INTRODUCTION

Students frequently believe they fully understand a topic while it is being covered in class, but actually do not (Willingham 2003). Research shows that two factors are especially important in causing this disparity: (1) the students' "familiarity" with a topic and (2) the students' "partial access" to information (Willingham 2003).

"Familiarity" is when a person or a topic appears to be familiar to an individual, even though the source of the familiarity is unknown. "Partial Access" is when an individual knows something about part of the topic. For example, a student might be asked a question that they do not know the answer to, but some related information comes to mind, which would make them think that they would recognize the correct answer if they could see it. A big problem with both "familiarity" and "partial access" in the classroom is that students may think they already understand the topic being taught, so they mentally shut down, which prohibits them from fully learning the topic (Willingham 2003). The students may then go home feeling confident in their knowledge, only to find out too late that they cannot complete their homework since they do not have the adequate comprehension. At this point, the teacher is not available to help answer any questions the student may have. Although there have been many methods employed to address this issue, such as varying teaching styles, one contemporary instructional technique called: Flipped Classrooms, has garnered popularity over the past 8 years. It has become popular because it suggests a sublte but important difference in instructional design, moving the dissemination of information to "home-based" efforts, where "in-class" efforts focus rather on lab and what was traditional "home-work" experiences. Nonetheless, despite its popularity there is limited research documenting its impact on student performance – specially in high school classrooms.

Note, for the duration of the paper the term: "traditional classroom" will refer to any teaching style where students come to class and the teacher presents content for the students to learn, and the students then practice what they were taught in school at home.

Flipping the classroom (a.k.a "flipped classroom," "flipped learning," or "inverted learning") is a teaching strategy that reverses the role of the classroom instruction and out-of- class homework. Students are provided instructional materials before class, which commonly involves a video lecture the teacher prepared in advance (Overmeyer, 2012). The students are required to watch the videos at home and take notes just as they would be expected to do during a classroom lecture. The students then come to class with a basic understanding of the content knowledge from the video and complete what is traditionally known as "homework" in class in collaboration with the teacher.

Goodwin (2013) stated, "To date there is no scientific research base to indicate exactly how well flipped classrooms work." The problem with understanding and accepting the flipped classroom as a valid method of instruction is that there has been little research done on the effectiveness of students' learning when using a flipped classroom model.

The purpose of this research was to add to the body of knowledge and help provide data investigating student attitudes about using flipped classrooms, and how well students learn physics content by using a flipped classroom model in a high school physics class.

Research Questions

Two research questions were investigated to address the research purpose. The questions are listed below:

1. Will exam scores of students in a flipped high school physics class differ statistically and practically from exam scores of students in a traditionally taught high school physics class when tested on content knowledge?

2. How will students' attitudes about learning and classroom environment differ between students in a flipped classroom from students in a traditional classroom?

METHODOLOGY

Seven periods of Physics with Technology (PwT) with approximately 28-32 students in each class participated in the study. Students in PwT consist mostly of sophomores (approximately 85%), with some juniors (10%) and seniors (5%). Four of the PwT classes were taught using traditional methods and three of the PwT's were taught using the flipped classroom. It was not possible to randomly assign students to different classes since students can select which courses to take. However, the classes can be considered quasi-randomly assigned since the computer that assigns classes uses an algorithm to place students in classes based on class sizes and availability. Although the individual students cannot be completely randomly assigned to a specific group, the classes were randomly assigned to either the control group or the treatment group by flipping a coin.

The Force Concept Inventory (FCI), a nationally accepted standard to measure students' comprehension of conceptual physics, was given to the students before instruction began to establish a baseline for each class period's entry level knowledge. The FCI was not used as a final exam since the three units taught during the research time does not cover sufficient information to see a noticeable difference in test scores. Instead, it was used to establish the baseline to compare and confirm that each period had similar average initial physics content knowledge at the start of the study.

Students in the treatment and control group were also compared by using their overall GPA prior to entering the physics class. Their overall GPA was the best method available to the researchers to compare students' previous study habits and learning aptitude. For example, if the average GPA for each class was comparable, we could assume that the students had similar baselines in educational aptitude and work ethic, and would perform equally well in their physics class if conditions were similar.

Three class periods were randomly assigned to participate in the treatment group as the classes that would be flipped. The flipped classes were told to watch the video lessons before class. A quiz about the video content was given online. The students had to complete the quiz before coming to class. The quiz scores were used to monitor which students watched the videos on time. At the beginning of class, the instructor led a class discussion, beginning with any questions the students had. The instructor was careful not to simply review the material in the video lesson again. The purpose of the discussion was not to give a complete review of the topic covered (although by talking about the subject, that automatically does become a review in and of itself), but to get feedback on what was not understood, or to give deeper explanations. Students then completed their "homework" in class in groups or partners with the teacher available to help, as well as work on labs or perform demonstrations of the concepts taught in the video.
The control group was four class periods that were taught using a teaching style that is commonly used to teach high school physics. This method primarily uses guided inquiry (i.e., students explore concepts by being engaged in hands-on labs that demonstrate concepts being studied before any formal lecture is given). Following the labs and activities, classroom discussions were led by the teacher to help refine and expand upon principles learned by the labs or activities. Students also

learned from demonstrations, lectures, discussions, and small group work. Students were then assigned homework problems that were similar to the problems and concepts learned in class that day. The following class period, students were administered a quiz to evaluate understanding on the previous day's content.

Content for both the control group and the flipped group was paced to match each day. All assignments, labs, activities, etc. that were recorded as part of students' scores were identical for both the control and treatment group. The instructor performing the experiment has experience with both the flipped classroom and guided inquiry methods of instruction.

At the end of the experiment, a survey was administered to each student to get their opinions towards the method of instruction they received. Questions 1-11 consist of a five-point Likert scale concerning their feelings towards school in general, how well they felt they learned in their physics class, and whether or not they prefer the flipped classroom model. The last few questions were open-ended questions where the students could share their comments about the class. The questions were:

1. Overall, I enjoy going to school.
2. I enjoy my physics class.
3. I feel like I understand the physics content taught in this class.
4. I like the way physics is taught in my class.
5. I feel like I do well on my assignments in physics.
6. I feel like I do well on my tests in physics.
7. I can see that I am improving in my knowledge of physics.
8. I know where to get help if I get stuck on a physics assignment.
9. B-day: How much do you think the Flipped classroom has helped you learn? (A day: How much do you think the flipped classroom WOULD help you to learn physics?)
10. How difficult is your physics class? (a score of "1" is considered very easy, "3" would be considered to be a challenging class, but acceptably challenging, and "5" would be considered extremely difficult)
11. How much time do you spend out of class on physics work? (A score of "1" would be considered very little or no time at all; "2" would be some time, but not as much as you would have expected for a physics class;"3" would be considered to be as much as you would expect for a physics class; a score of "4" would represent that you spend more time than you expected out of class for a physics class, but it does not consume all of your free time; and a "5" is way more than you would expect for a physics class and it takes up most or all of your free time.)
12. What did you like the most about the flipped classroom?
13. What did you like the least about the flipped classroom?
14. Are there any other comments you would like to share that relate to the flipped class?

FINDINGS

The FCI was administered to both the treatment and control groups in the first week of school before any instruction on forces and motion had been given to either group. Both groups were compared to see if any difference in baseline knowledge existed that would skew the results. Figure 1 shows the results of the FCI:

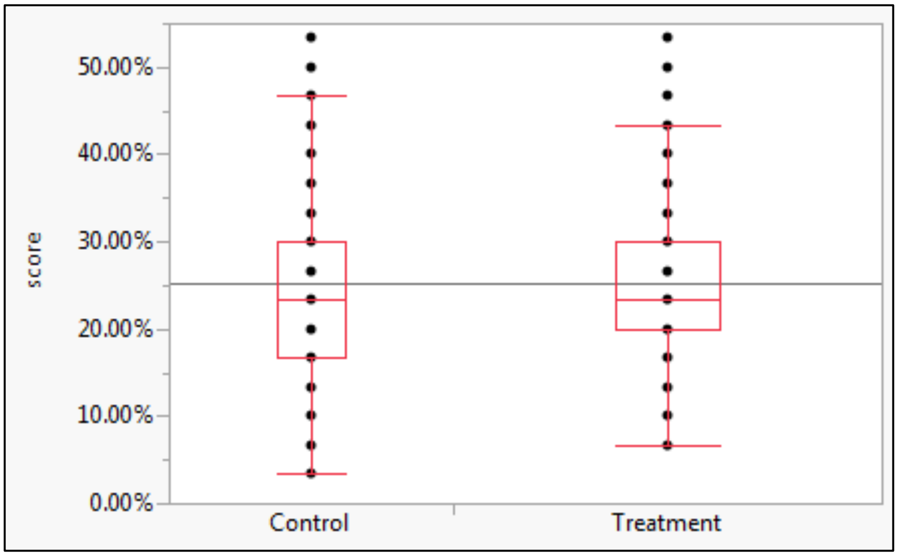

Figure 1: FCI

The mean score for the control group on the FCI was 0.2397 ($\bar{x}$ =23.97%) with a standard deviation of 0.113. The treatment group had a mean of 0.259 ($\bar{x}$ =25.9%) with a standard deviation of 0.104. The two-sided p-value from a t-test with α=0.05 was reported to be 0.3008 which is large enough to determine that the difference in mean scores for the FCI was not statistically significant since any p-value larger than 0.05 is considered to be not statistically significant.

We also compared the mean GPA of the students' previous school year. Figure 2 shows the comparison.

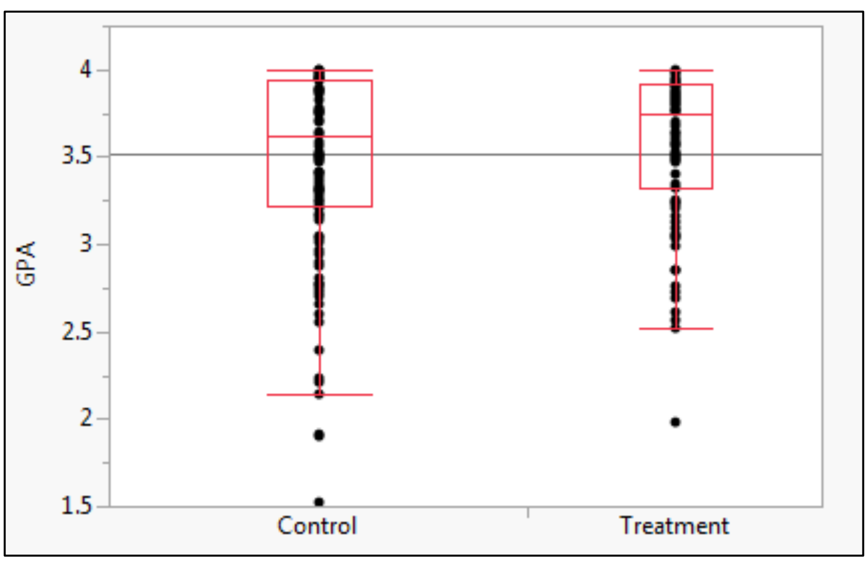

Figure 2: Cumulative GPA

The mean GPA for the control group was found to be 3.49 with a standard deviation of 0.534. The mean GPA for the treatment group was 3.56 with a standard deviation of 0.467. The two-sided p-value of a t-test with $\alpha=0.05$ was 0.3413 which is large enough to show that the difference in means was not statistically significant.

By comparing the mean scores on the FCI, as well as comparing the previous year's GPA, we did not find any statistically significant difference in baseline knowledge between the control group and the treatment group. For this reason, we can assume that any difference in means on their end-of-unit test scores can be attributed to the method of instruction used.

The first research question asked if there would be a statistically or practically significant difference in mean test scores between students participating in a flipped classroom vs students in a traditional classroom. Each test was analyzed individually to determine if there was any statistically or practically significant difference in means between the control group and treatment group. The end-of-unit tests are summarized in Table 1.

Table 1: End of Unit Tests

End-of-Unit Test	Mean Score (Control)	S.D. (Control)	Mean Score (Treatment)	S.D. (Treatment)	P-value ($\alpha=0.05$)	SMD Effect Size
Unit 1	81.95	14.66	82.65	13.74	0.719	0.0500
Unit 2	78.85	19.07	79.72	14.83	0.7204	0.0509
Unit 3	65.82	19.09	67.56	18.09	0.5100	0.0935

All three end-of-unit tests were compared using ANOVA to control for the increased probability of an alpha error due to multiple tests being conducted. Mean unit test scores were also compared using SMD effect sizes to determine any practical significance. It was found that none of the three end-of-unit tests had any statistically or practically significant difference in means. Although the mean test scores show that there was an overall trend of decreasing test scores, each unit test cannot be compared to the others. Each unit's test covers different topics and had different levels of difficulty.

When comparing survey answers nearly none of the questions had either statistical or practical significance (see table 2: Survey Responses).

Table 2: Survey Responses

Question	Mean (Control)	Mean (Treatment)	Standard Deviation (Contr	Standard Deviation (Treatm	P-value	SMD Effect Size
1. Overall, I enjoy going to school.	3.472	3.695	0.8908	0.8268	0.0798	0.259
2. I enjoy my physics class.	3.203	3.28	1.074	1.103	0.6301	0.070
3. I feel like I understand the physics content taught in this class.	3.38	3.476	1.213	1.135	0.5794	0.081
4. I like the way physics is taught in my class.	3.352	3.427	1.071	1.267	0.6593	0.063
5. I feel like I do well on my assignments in physics.	3.565	3.39	1.087	1.194	0.2949	-0.153
6. I feel like I do well on my tests in physics.	3.333	3.28	1.26	1.289	0.7771	-0.041
7. I can see that I am improving in my knowledge of physics.	3.806	3.817	1.089	1.017	0.9443	0.010
8. I know where to get help if I get stuck on a physics assignment.	4.009	4.073	1.164	1.131	0.7048	0.055
9. B-day: How much do you think the Flipped classroom has helped you learn? A day: How much do you think the flipped classroom WOULD help you to learn physics?	2.778	3.219	1.2177	1.187	0.0131	0.366
10. How difficult is your physics class?	3.333	3.195	0.8424	0.9615	0.3029	-0.152
11. How much time do you spend out of class on physics work?	2.907	3.024	0.08033	0.0922	0.3400	0.138

The exception was Question 9, which was statistically significant and had a moderate amount of practical significance. For questions 12-14, there were a variety of responses. It is impractical to list each individual response from over 200 students, but there were a few themes that were repeated by a number of students. These responses are listed below (number of students who expressed a similar idea is listed in parentheses).

Positive responses:

"I like that we do homework in class where (the instructor) is there to help." (22)

"If I needed to look back on something I had learned, I was able to do that easier." (12)

"It gives me an opportunity to learn how to learn on my own." (2)

"Class time was more fun and engaging." (2)

Negative responses:

> *"Not being able to ask questions to the video." (10)*
>
> *"It was hard doing one flipped classroom and having all of my other classes be the regular. It really threw me off." (3)*
>
> *"I felt like I couldn't learn as well this way" (4)*
>
> *"I didn't like doing the OHW in class." (2)*
>
> *"I don't really like watching videos to explain what I'm learning. I like it better to do it during class, that way when we are learning something new we can ask questions and understand the concept better before doing it on our own." (9)*

There was also one phenomena that came up that contradicted itself. Some students expressed the desire to spend more time in class reviewing the material since they didn't understand the video very well. Others expressed frustration that the class discussion took up too much time and we were just covering the exact same stuff they already learned from the video. Pacing is a common problem in education. It was expected that the flipped classroom would alleviate this issue, but it still persisted. However, it is uncertain if the flipped classroom has helped to alleviate as there is no data from both groups to compare how well the flipped classroom potentially alleviated the pacing problem.

When asked for any additional comments (question 14) there was one insight from a student that stood out to the researchers:

> *"I think that normal class room and a flipped class room will yield the same results…because it truly depends on the students own work ethic and self-control. You could alter the class room as much as you would like but when it comes down to it, it really just depends on the students own integrity."*

CONCLUSION

Based on the data gathered in our study, students in flipped physics classes perform equally well as students in traditional inquiry-based classes. The traditional method of instruction in the experiment was based on guided inquiry methods, which has been shown to be an effective method of instruction, especially in science classes (Barthlow 2014). Students began the unit with hands-on learning opportunities with a lab that demonstrates the major concepts being studied in the unit. Students were guided through the lab and discovered the scientific principles on their own. Students in the flipped classroom performed the same experiments, demos, and lessons, but received instruction before class with video lectures. Since they had already learned much of the material at home, the in-class activities became more confirmation-based learning (students perform activities that confirm their knowledge), rather than inquiry-based learning (where students discover concepts on their own). Since students in the flipped classroom performed equally well on their end-of-unit exams as the traditional students, it can be concluded that the flipped classroom is equally effective as guided inquiry for high school physics classes. This finding is especially impressive as there were several major limiting factors that occurred in the flipped classroom that are described below.

A major issue that came to light during this research study was the frequency in which the students were watching the assigned videos before class. The instructor reported that students frequently came to class unprepared by not having watched the videos ahead of time. The instructor made as many arrangements and accommodations as possible to encourage and remind students to watch the videos before coming to class. Announcements were given vocally to the class each day, as well as written on the whiteboard for all the students to see and listed on the calendar on the class website.

Students were given an online quiz to complete immediately after watching each video. There was no feasible way to track the actual videos being watched, so the quiz scores were used to match which students had watched the video on time. By looking at the quiz scores 68% of the students came to class having already watched the videos before class. However, it was not possible to tell if and how many videos were watched late, and the number of times they were watched. To further investigate the frequency that videos were watched on time, watched late, and/or watched repeatedly, students received an anonymous three question follow-up survey. The three questions were:

1. How often did you watch the videos on time?
2. How often did you watch each of the videos in total (both on time and late combined)?
3. How often did you re-watch each of the videos?

The three questions were based on a five-point Likert scale: a score of five on the survey would represent all or almost all of the videos, a four would be approximately 2/3 to ¾ of the videos, three would be approximately half of the videos, two would be approximately ¼ to 1/3, and a score of one would be none or almost none of the videos.

The students reported they had watched the videos "on time" with a mean response of 4.03 out of 5. Since a score of four corresponds to a 2/3-3/4 ratio of videos watched, their self-reported answers coincide with the results found from looking at the quiz scores with 68% watching the videos ahead of time. This is similar to the findings of Gaughan who found 72% of students came to class prepared on average each day (Gaughan, 2014).

Students responded to Question #2 (total time watching the videos – on time or late) very positively. The data showed a mean response of 4.59. Meaning, of the 80 survey responses, 71% responded with a five, suggesting that 71% of the students watched all or nearly all of the videos at some point during the unit being studied. Another 21% of the students responded with a four, which corresponds to those students having watched 2/3 to 3/4 of the videos. Only two students (2.5%) responded that they watched none or nearly none of the videos.

Students responded to Question #3 (i.e., frequency of re-watching the videos) with a mean response of 2.4. The majority of students reported that they rarely re-watched videos (28.75% responded with a one, and 30% responded with a two). 18 students (22.5%) responded that they re-watched approximately half of the videos, eight (10%) responded that they re-watched between 2/3 and 3/4 of the videos, and seven (8.75%) of the students re-watched all or nearly all of the videos.

If on any given day, only 68% of the students watched the video the night before, this poses two major questions that teachers of flipped classroom need to be aware of: What are they going to do in their lesson plans to accommodate the 32% of the students that are not prepared for that lesson? And what are they going to do to motivate the approximately quarter to one third of the students who regularly show up unprepared? To answer to the latter question, it is important to understand the students' motives for not watching the videos before class.

Students were interviewed face-to-face in focus groups so that the interviewer could ask probing questions regarding the flipped classroom. The treatment group was split into three separate focus groups and the same question was asked to each group, although follow-up questions varied from group to group depending on students' responses.

Students were asked what limiting factors played a role in preventing them from watching the videos before class began. The interview was designed to leave the question open ended so students could respond with their specific situation, rather than feel like their answer had to fit pre determined responses. Because the interview was open ended, there was little quantifiable data to help determine how many students struggled with each of the provided responses. However, the interviewer took notes during the three focus groups' interviews to compare answers between the three groups.

The most common comment made in each of the three focus groups was that the students simply forgot to watch the videos. Although a specific count of the number of students who agreed with that comment was not recorded, the interviewer noted that many students either nodded silently in agreement, or vocally addressed similar comments. Based on the reactions and comments made regarding the limiting factors of watching videos on time, it is believed by the interviewer that this was the most common problem among the students. In each of the three focus groups, the follow-up question to the comment on forgetting to watch the videos was whether homework in general is hard to remember, or if watching videos specifically was harder to remember than doing a "regular" homework assignment. A few students replied that the videos were harder to remember than "regular" homework. The students claimed that since watching videos was so easy to do, they did not worry about it, and therefore forget to do it when they get home. However, even though a few students believed the videos were specifically more difficult to remember, a majority of students who said they sometimes forgot to watch the videos said that homework in general is hard to remember to do. Additionally, the students stated that the big drawback they find with the flipped classroom is that with a traditional "paper homework" assignment, if they forget to do it, they can work on it in a different class the next day before turning it in to the assigned class. Since the flipped classroom's homework was to watch videos, it was more prohibitive to do those during other classes than a traditional homework assignment.

Another common topic in each of the three focus groups was that there were occasional technical issues that prevented them from watching the video on time. The term "technical issues" in the context of the interview consisted of two main issues: Non-functioning computers and unavailable computers. Non-functioning technical issues involved computers that had crashed or had Internet connection problems. Unavailable computers meant that the students had access to a computer, but it was unavailable due to siblings also working on homework, or their computer filters blocked YouTube, where the video was hosted.

The rest of the comments were similar to excuses for not doing any type of homework assignment. Several students freely admitted to "being lazy" and just not wanting to do their homework, even though they knew they had homework due. Other students reported that they simply did not have time to watch videos at home because of extensive extra-curricular activities and work schedules. When asked if that was a problem unique to the flipped classroom or if it occurs with all homework, the students responded it is a common problem with all homework. These comments from students partially confirm Nielson's findings: that students, especially K-12 students, are unmotivated to do homework (Nielson, 2012).

In two of the three focus groups, the conversation lead the interviewer to ask a follow-up question about how many students still prefer the flipped classroom method in their physics class, despite the complications they faced with the videos. Approximately 80% raised their hand to signify they would prefer to continue with the flipped classroom for their physics class. No claims can be made regarding whether students would prefer this method for all of their classes as it was asked only if they would like to continue using the method in their physics class.

The focus group interviews also revealed that the majority of the problems surrounding the issue of not watching the videos on time are not unique to the flipped classroom, but are encountered independently of which type of homework is given. This leads the researchers to believe that this issue is most likely not easily fixed by making small changes in how the flipped classroom is implemented by the instructor, but is a serious issue that will most likely occur regardless of how carefully an instructor implements the flipped classroom. However, this is an area that needs to be investigated with more research.

Based on the findings of this study, we conclude that the flipped classroom is a viable method of instruction. We believe this because despite the complications of motivating students to proactively watch the videos on time, the flipped classroom students scored equally well as the students in the traditional classroom. Additionally, student attitudes towards flipped classroom was positive. The point of this project was not to bias educational stakeholders for or against flipped classrooms, but rather gather quantitative and qualitative data to describe if flipped classrooms perform at, above, or below the level of traditional classrooms. In the classroom settings described in this research report, flipped classrooms are as effective as traditional classrooms.

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