

INVESTIGATING THE EFFICACY OF A FLIPPED SCIENCE CLASSROOM  
MODEL

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## ABSTRACT

An introductory honors level high school biology course was used to implement a flipped classroom model in the topic of biochemistry. Ten-minute lecture videos were recorded and collaborative work was completed during class. Surveys and questionnaires were used to collect data about student preference. The results indicate that students enjoyed their class more and learning biochemistry in this way was preferable to the traditional in-class lecture format.

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**CLASSROOM MODEL**

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## INTRODUCTION

I currently teach at St. Andrew's Episcopal School Upper School in Austin, TX, a city of approximately 700,000 people. Our 400 students hail from various backgrounds, but the majority are upper middle-class Caucasian students. Twenty four percent of our students self-identify as racially or ethnically diverse, 17% of our students receive some form of financial aid, and 6% of our students identify with a religious tradition other than Christianity. St. Andrew's is a college preparatory high school, and as such, strict criteria must be met in order to gain admittance to the school. There is an air of academic rigor at the school, especially in the sciences, and students are expected to perform well. Students are expected to take only three years of science; many fourth year students take advanced placement science courses (St. Andrew's Episcopal School, 2012).

In my ninth grade biology class, the first topic we learn is biochemistry. Historically, biochemistry is one of the most difficult topics for students to understand because they have not yet taken a full year of chemistry. Some of the concepts are familiar to them, such as a periodic table, but they are unfamiliar with the basic properties of atoms such as electronegativity and ionization energy. We cover the topics of properties of carbon, carbohydrates, proteins, and lipid chemistry. The large-scale inquiry lab completed for this unit focused on enzyme activity. An additional complication is that many of my students are involved in sports activities and can miss classroom content as a result of frequent statewide travel. The repeated absences and missed content led the school to convert our fixed schedule to a rotating 7-day model. While the schedule change has alleviated the issue of students missing biochemistry classes, it has not alleviated the struggles that many face with the biochemistry content.

I initially discovered the flipped classroom model while attempting to solve the student hatred of biochemistry and teacher frustration of teaching the class. The concept of flipping a classroom is a relatively recent development, though it has gained much attention in educational circles. The term “flipped classroom” is most often attributed to Aaron Sams and Jonathan Bergmann, who began using screencasts and podcasts to deliver content to their high school chemistry classes in 2006 (Makice, 2012). Bergman and Sams attempted to deal with the same issues many teachers have in their classrooms: students needed assistance for homework completion, heavily-involved students were missing classes and content due to traveling for sports and other activities, and students with learning differences struggled to stay caught up during class lectures (Bergmann and Sams, 2012).

It is an objective of our curriculum that students understand the molecules that form the basis for all biological processes. In order to understand the function, we want them to first understand the structures. Unfortunately, the human brain did not evolve in a world where perception of quantum physics was necessary. Survival of human ancestors depended on perception of mesoscopic events, and as such, is specifically geared towards understanding on this scale. This explains the extreme difficulty that many students have developing an understanding of extremely small or extremely large-scale processes (Singer, 2009). When we ask students to consider the underlying molecular events of protein expression, for example, we are asking them to stretch their minds well beyond what most are naturally capable of doing. In order for students to understand the underlying explanations of biological phenomena, we must build

representations in a scale that the brain is naturally capable of processing (Gobert & Buckley, 2000).

Since Piaget's time, there has been heavy debate about the cognitive development of children through adolescence and questions about the abilities of adolescents to think in increasingly abstract terms. Marini and Case (1994) showed that the ability to think in abstract terms begins to develop between ages 11 and 12, but they also showed that the number of tasks imposed limits the further development of abstract thinking ability. Furthermore, Marini and Case illustrated that most adolescents develop at the same rate, although there are a few individuals who were more advanced in either the development or the rate at which they progressed.

In order to ensure that the majority of students are learning in the classroom, abstract concepts must be introduced by correlating specific abstract thinking tasks with concrete tasks. Knowledge is inference, and it takes place through active comparisons of information over time (Magnani, 2004). Because only those concepts that have meaning to individuals will produce neural activity (Berthoz, 2009), for students to internalize abstract concepts in the early stages of adolescent development, said concepts must be presented in both a rate and form that students can actually consider. This was one of the main goals of this research: to introduce students to content *before* asking them to work with concrete objects such as models and other laboratory materials. By using video recorded lectures as homework the night before a lab or demonstration, students are better prepared to understand the connection between the concepts and the tasks they are asked to perform. By having my lectures recorded on video, students are then able to re-

experience content at a time that is convenient for them as many times as necessary to understand the abstract nature of molecular biology.

It is well known that what students actually learn in the classroom depends heavily on how they are taught. It has been shown that the majority of average or underachieving students are active, kinesthetic learners (Wilson, 1996). In 1991, McComas identified specific standards that are essential to excellent laboratory instruction, including tactual and kinesthetic presentation of materials, teacher-as-facilitator models, and brief passive student listening during introduction of the material (as cited by McManus, Dunn, & Denig 2003). In their study published in 2003, McManus, Dunn, and Denig found that when students were actively involved in the classroom via tactual and kinesthetic resources, their attitudes and test scores significantly improved. Furthermore, students who constructed their own models improved in attitudes and test scores significantly over both students working with teacher-constructed models and traditional lecture-based formats.

Thus, I sought to find a way to limit the amount of content delivery in the classroom and focus more on working with the students during class time through the use of models and labs. The content still needed to be delivered, however, and reading the textbook at home was no more effective than attending a lecture in class. This eventually led me to discover the idea of “flipping” my classroom. Once I decided to employ this technique in my own classroom, I had to decide on an approach for the video content and a way to ensure that the main points of the video content were conveyed to the students. In this study, I sought to answer four questions:

1. What experience do students have with online learning?

2. Can this instructional model improve student enjoyment of learning biochemistry?
3. Will students feel like they are learning without in-class lectures?
4. Will students find having the recorded lectures helpful for studying and when absent?

## METHODS

After investigating several styles of flipping a classroom, I followed the approach of Mr. Paul Andersen, science teacher and technology specialist at Bozeman High School in Bozeman, MT. Mr. Andersen holds a M.S. in Science Education and was the 2011 Montana Teacher of the Year (Andersen, 2012). The technology that he employs is very similar to the technology that I already use and am familiar with, which was a big factor in my decision to approach the lecture videos after his fashion. In his video “How to Make an Educational Screencast,” Mr. Andersen outlines the basic hardware, software, and techniques that he uses to make his dynamic videos (2010). Being something of a tech-junkie myself, I quickly adjusted to the extra hardware and began making my videos.

I made 10 videos in total, ranging from a short review of basic chemistry to the complexities of enzyme function. Each video was kept at around 10 minutes in length, with the longest video being around 12 minutes long. Following Mr. Andersen’s advice, students can only functionally concentrate on videos for about that length of time (2010). I then used a website that our school regularly uses called Quia to create a series of homework quizzes to highlight the important information from each video. A typical homework assignment looked like this: students would go to the video webpage and

watch the video assigned for the evening and then complete the quiz as a product to show that they had watched the video. The students were allowed to take the quizzes as many times as they liked in order to get the homework score that they were happy with. Class time was spent using the material from the previous night. For the initial videos of a particular topic, we worked with organic chemistry models sets to build various examples of the types of molecules discussed in the video (carbohydrates, proteins, and lipids). As the videos covered the subjects more in depth, students used the models to build polymers of the molecules and to model the processes of synthesis and decomposition common to these three classes of macromolecules. We then would complete a lab or demonstration with actual materials to illustrate the processes unique to each class of macromolecules.

Data were collected in two different ways using the Tucker Flipped Classroom Student Survey: 1) a survey administered to students to assess student opinion and 2) a survey to collect qualitative data about student experience (Appendix A). The survey administered was constructed on a Likert scale with the responses defined as: *1=not at all, 2=maybe a little, 3=somewhat, 4=more often than not, and 5=very much*. Students were also asked whether or not they had used online videos for academic and non-academic purposes. In order to gather qualitative data about the students' experience, they were also asked to describe their experience during class and while doing homework over the course of the unit. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

## RESULTS

### *Student Experience with Online Learning*

Prior to viewing any of the lecture videos, students were asked about their previous experience with online academic and non-academic videos (Figure 1). While 58% of students responded that they had previously watched an online video to learn more about academic topics, 85% of students had used online videos to learn about non-academic topics. When asked about the specific academic topics that they had looked up online, answers ranged from “time, space and the universe” to “for English class, I found a video about *Ramayana*,” which is a book used in their current humanities classes. Some students had sought out math help online for their current math classes as well. The 85% of students watching non-academic online videos were looking up such varied topics as how to do foreign accents, cooking, sewing, and how to apply makeup. One student responded, “I watched a video about how to make a mini-taser out of a disposable camera.” In fact, the majority of students (81%) watching non-academic videos included “how to” in their description.



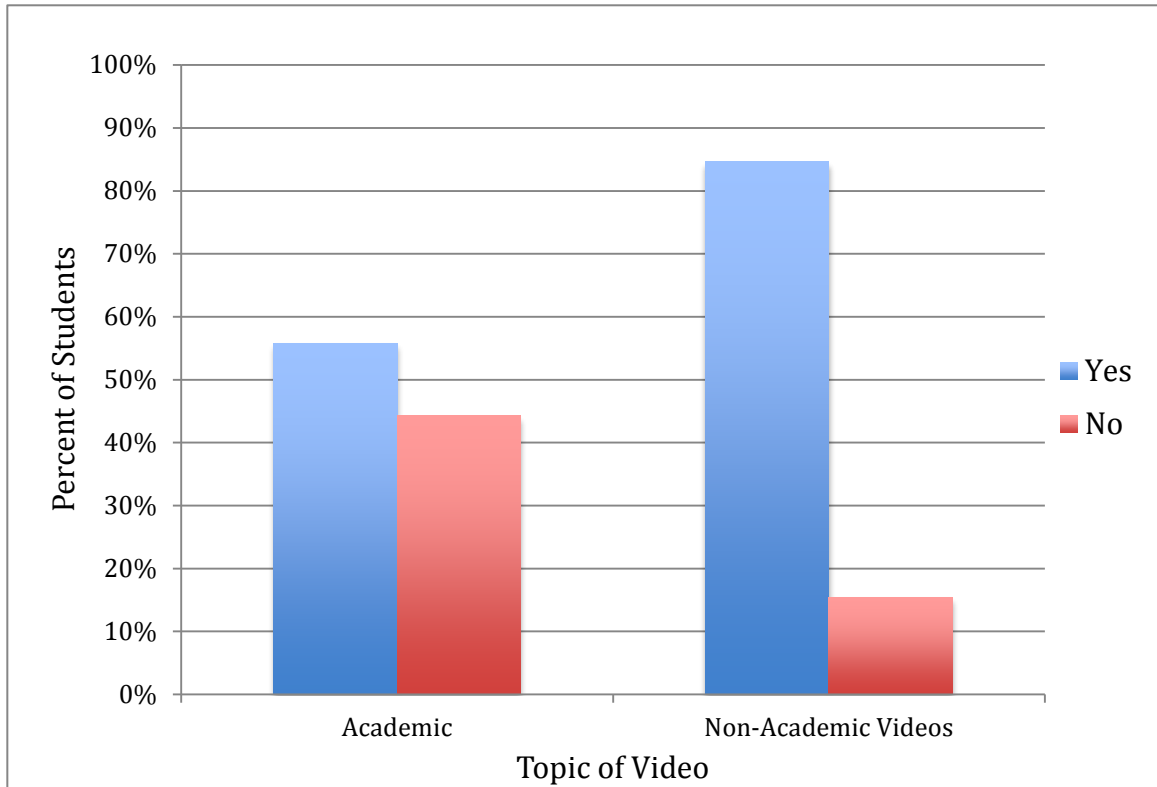


Figure 1: Student Familiarity with Online Videos (N=52)

### *Student Enjoyment of Online Videos and Quizzes*

Students were then asked to rank their experience using the biochemistry videos and quizzes on three separate qualities: enjoyment, amount learned, and helpfulness. Each of these categories used the same Likert scale, with a value of *1=not at all*, *2=maybe a little*, *3=somewhat*, *4=more often than not*, and *5=very much*. The first category considered was how much the students enjoyed using the Flipped Model as a classroom structure (Figure 2). Sixty-five percent of students reported that they enjoyed using the videos as a substitute for lecture with responses of four or five on the given Likert scale ( $N = 52$ ). Both the median and the mode for student enjoyment of videos was

a response of “4.” When students were asked how much they enjoyed taking the quizzes as a homework product, 60% of students responded with rankings of four or five (Figure 2). Again, both the median and the mode had a value of four for this category. The reasoning for such high ranking of their enjoyment was consistent according to student comments. All students who ranked their enjoyment the highest liked the videos because of the time freed up in class. One student wrote, “I felt like class time was used to do more interesting things [sic] and learn deeper into the subject.” Another student went into a bit more detail, saying, “I feel that class time was used very efficiently in the absence of lectures. We had plenty more time to work on projects and such. I felt that there was a lot more hands-on work than I've had in the past. I am getting a lot of individualized attention which is helping me exponentially.”

Only two students reported that they didn't enjoy watching the lecture videos at all. One student who ranked their enjoyment of the videos as a one preferred learning from the textbook and stated that the quizzes were more helpful than the videos. This student ranked all of each category at one or two, although they stated, “The class was much better!” Four out of the seven students who ranked their enjoyment of the videos on the low end of the scale wrote that they had problems focusing on the lectures at home and would have liked to hear the lectures in class as well. For one of these students, they “just couldn't get used to hearing my teacher in my house. It was weird.”

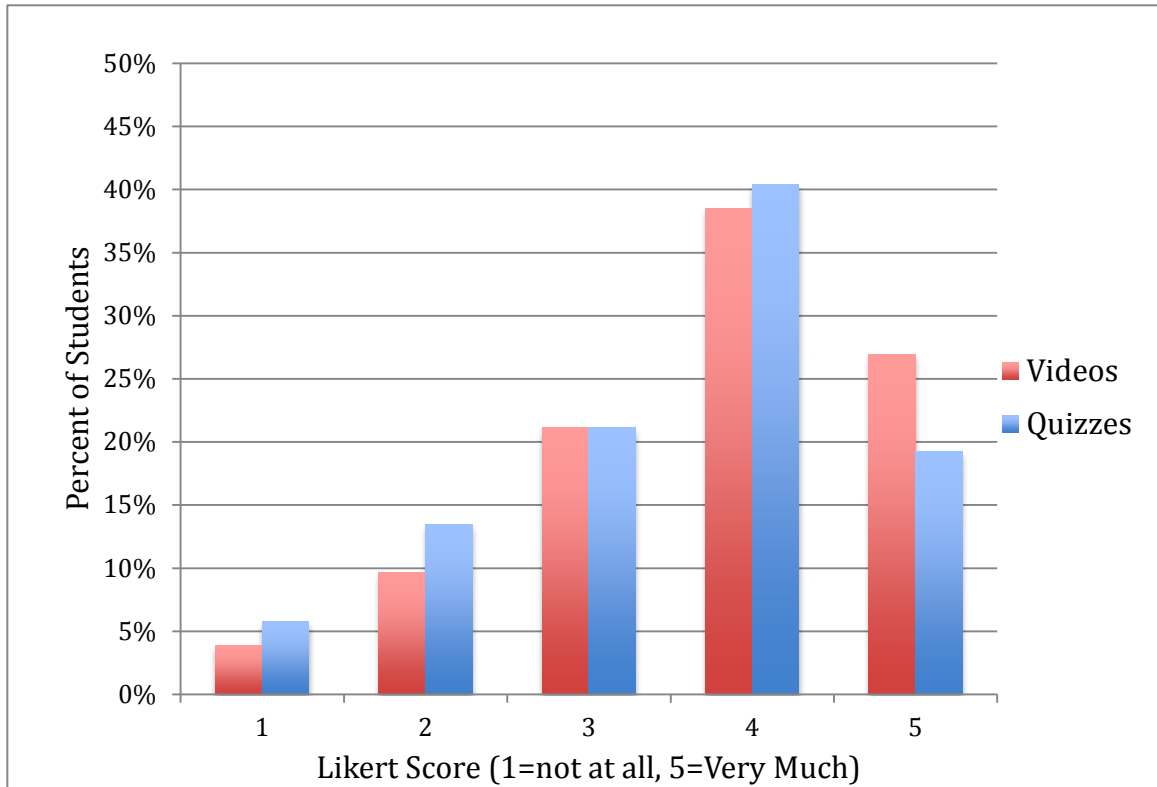


Figure 2: Student Enjoyment of Videos and Quizzes (N=52)

### *Student Experience Learning from Online Videos and Quizzes*

The second category considered was whether or not the students felt like they learned the material with the classroom constructed in this way (Figure 3). Fifty-six percent of students responded that they felt they had learned from the videos by ranking this statement as a four or five. Seventy-eight percent of students responded that they had learned from taking the quizzes by ranking this statement as a four or five ( $N=52$ ). Both the median and the mode for each of the categories was the value “4.” There were no students who responded that they hadn’t learned anything from taking the quizzes, while only one student responded that they hadn’t learned anything from watching the videos. This student was the same student who preferred to learn from reading a textbook.

For the students who ranked the amount they learned from the videos and quizzes at the higher end of the scale, the comments were consistently full of praise. Many students (67%) were appreciative of the increased hands-on time during class and stated that it helped them “understand the concepts better” because they didn’t “have to sit through boring lectures.” Ten percent of students noted that it was really helpful for them to have a basic grasp of concepts before coming in to class, while 15% of students really wanted to review more of the material in class after having watched the videos. They felt that “it’s easier to ask questions and remember questions in class.” One student self-identified as a visual and kinesthetic learner, and said, “I am a very visual learner and taking the time during class to put together models and do projects helped me immensely.”

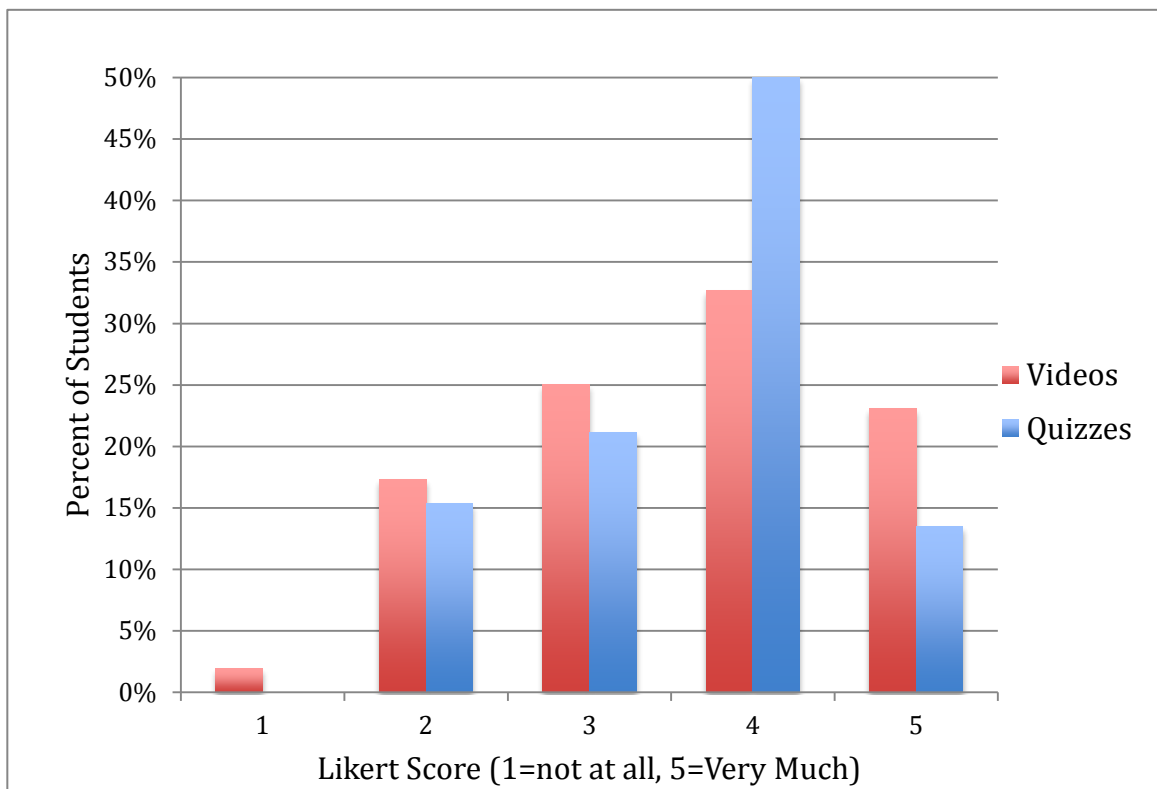


Figure 3: Amount Learned from Videos and Quizzes (N=52)

*Helpfulness of Online Videos and Quizzes*

The third and final category that students were asked regarded the perceived helpfulness of having the lectures recorded on video and taking the quizzes after watching the video lectures (Figure 4). Seventy-one percent of students found the videos helpful with a ranking of four or five for this statement. The median for this set of data was the value “4,” while the mode for this statement was “5.” Seventy-one percent of students also found the quizzes to be helpful with ranking values of four or five. Both the median and mode for the helpfulness of the quizzes was the value “4.”

Many students noted how great it was to have the lectures recorded and watched the videos many times more than they were required. One student remarked, “I feel that the videos really did help me, especially when I didn't understand anything I was able to watch the video again.” Students took advantage of the fact that they had all of the lectures on video, and could stay caught up with class even when they were absent, stating that the videos would be helpful as “a review or if you missed school then you know u [sic] can always catch up by watching the videos.” Not all students were singing its praises, however. Despite the increased hands-on time during class, one student remarked, “I think that I would learn more from listening to lectures in class and doing less hand on things.”

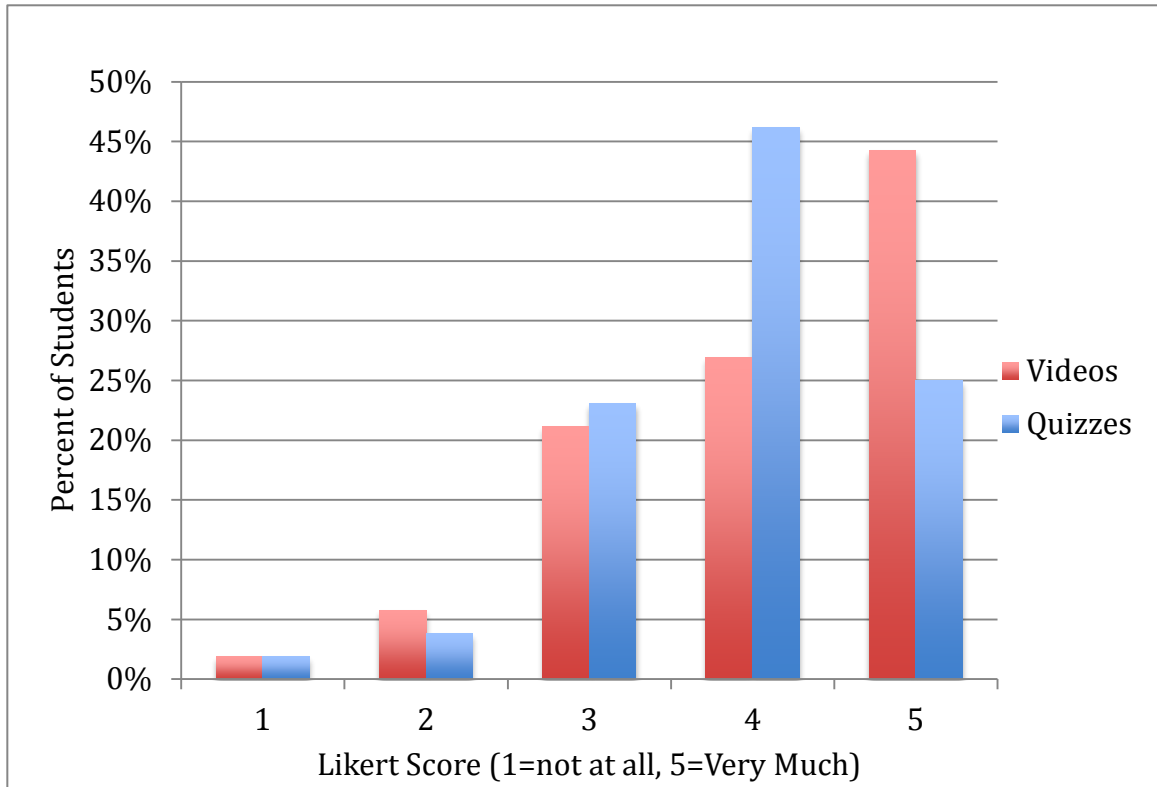


Figure 4: Helpfulness of Videos and Quizzes (N=52)

## CONCLUSION

Overall, I found that students were open and receptive to the approach of reconstructing the classroom following a flipped model. The majority of students had much experience using the internet to learn a myriad of topics; most that had watched a non-academic video included “how to” in their subject description of the video, indicating that they are both familiar and comfortable seeking out instructional information online. Much anecdotal evidence has been in the media in recent years about the effectiveness of many different flipped classroom models, despite the variations in approach. In my opinion, it is because of this variation that teachers and students have found the approach so effective. Every classroom and every population of students varies,

from period to period and from year to year. Teachers are able to adapt the flipped approach to both their budget and their students, which in turn makes it a dynamic way to address the needs of a particular culture, a particular class, and even a particular student.

I was concerned at first that students would not be able to readily adapt without having an actual textbook, but in fact only two students specifically mentioned the lack of a textbook in their survey. Digital materials that supplemented the videos were made available, as was an outline of all the pertinent information to be learned in the unit. As an educator, I am first and foremost concerned with whether or not the students are learning the material, but I also want my classroom to be fun and engaging. While exam scores didn't improve as much as I hoped, the students enjoyed the class more. Forty-eight percent of students, regardless of their ratings in any other surveyed category, remarked that the class was simply more fun than any other science class they've had. One student even said, "I loved flipping the class. We got lots more time to do hands on things (which really helped me). Flipping the class is an awesome! Whoever thought of it deserves a reward." This indicates to me that this is a worthwhile endeavor and worth future investigation for other topics in our course. To help illustrate these ideas, I created a Wordle using all of the feedback that students provided in the survey (Figure 5). One can easily see which terms were repeated more often based on their size relevant to one another.





Students also commented that they needed a recap of the material in class. I think this would be beneficial for students that would forget what questions they had about the material until we were involved in a project, demonstration, or some other activity during the class. Students in this age group tend to be reticent about asking questions during class, especially so early in the year. One way to remedy this situation might be to require students to bring a question about the video content to class and have a 10-minute question and answer time at the beginning of each class. Even if students are hesitant to ask questions in class early in the year, they might get their questions answered in this session.

I was not surprised that students readily adapted to this new form of learning. After only a few days, most had shifted and enjoyed immensely the experience of never having to sit through a science lecture during our 50-minute classes. The next area to investigate is what impact this form of learning might have on student grades. While some preliminary data were collected and compared to last year's scores, they were inconclusive and from such a small population of students they offered no real evidence of the effectiveness of this model. To design and take into account all the criteria necessary to support a hypothesis would be a vast undertaking, to be sure. However, the merits of such an undertaking are clear, and in order to gain a larger audience with this approach, the research will be necessary. The main conclusions of this study can be summarized as follows:

- High school students are not as jaded as the media tells them to be. If the classroom is engaging, the majority of students will be engaged.
- If you broadcast it, they will watch. Students love watching videos and love to see their teachers' faces on the Internet. The profession should take advantage of this fact before the novelty wears off.

- Relationships are essential, and no amount of recorded video can take the place of a real person. Isn't that why we all teach?
- No matter how intriguing, engaging, or entertaining a classroom is, some students will still refuse to participate. Addressing these issues is outside the scope of this study.
- Having numerical data about student effort is essential in dealing with parents. The Quia quizzes were graded automatically, as well as the number of attempts recorded. When a parent would inquire about their student's grade, I need only direct them to their student's Quia page and let the data tell the story. One might ask, it's great that students enjoy this approach more, but what effect

does it have on their exam scores? In my experience and opinion, grades are somewhat important, but we have focused far too long solely on students' grades. For right now my goal is that my students are excited about learning. This experiment was a success in my eyes, simply because I didn't have to see the glassiness in their eyes while I waxed ecstatic about the fascinating way that proteins form, or how cool it is that despite the biodiversity on this planet, everything is made of the same basic molecules. I showed them in class, using the time freed up by flipping my classroom. They came into class eager, informed, and ready to play, and that is everything that I had hoped for.

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APPENDICES

APPENDIX A

TUCKER FLIPPED CLASSROOM STUDENT SURVEY

### The "Flip" Technique: Turning a Classroom on its Head

Please answer this survey as completely and as thoroughly as you are able. We are researching this technique of teaching to potentially extend the video lessons to the entire biology class, and perhaps other science classes as well. NOTE: Your participation in this project is voluntary. Your responses will only be used for data collection purposes and are not tied to you or your grade in any way.

\* Required

1. Have you ever used an online video to learn about a non-academic topic? \* e.g. how to make something, or do something, not related to school

- Yes
- No

2. If so, what was the topic of the video? \* Type NA if you have never watched an online video to learn about a non-academic topic.

3. Have you ever used an online video to learn about an academic topic? \*

- Yes
- No

4. If so, what was the topic of the video? \* Type NA if you have never watched an online video to learn about an academic topic.

5. Please rate how much you ENJOYED working with the online videos. \*

1    2    3    4    5

Hated it      Loved it

6. Please rate how much you ENJOYED taking the video quizzes as a homework "product." \*

1    2    3    4    5

Hated it      Loved it

7. Please rate how much you feel you LEARNED from watching the Biochemistry videos. \*

1 2 3 4 5

Nothing      Everything about the topic of the video

8. Please rate how much you feel you LEARNED from taking the video quizzes. \*

1 2 3 4 5

Nothing      Everything about the topic of the video

9. How HELPFUL was it to have the lectures recorded on video? \*

1 2 3 4 5

Useless      Extremely Helpful

10. How HELPFUL was it to take the video quizzes after you watched the video? \*

1 2 3 4 5

Useless      Extremely Helpful

11. Please describe your CLASSROOM experience during the biochemistry unit. \* Do you feel that class time was used efficiently in the absence of lectures? Do you feel you got more hands-on work? Did you get more individualized attention than in a traditional classroom?

12. Please describe your HOMEWORK experience during the biochemistry unit. \* Did you spend any time at home studying OTHER than the assigned video and quiz? Do you feel you actively focused on the video lecture? Did you watch the video and then take the quiz, or look at the quiz first, or have both open at the same time?