The Impact of Flipped Instruction on the Subject Knowledge and Test Scores of High School Pre-Calculus Students

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Introduction

I am a convert to mathematics. In middle school I got pretty good grades when I tried but there were instances when I definitely didn't apply myself and sometime in my freshman year of high school I graduated from not caring about math to disliking it. For reasons both personal and external, by the time high school was finishing up I wanted nothing more to do with school, especially math, and so I joined the U.S. Army. After a couple years I wanted to start exercising my brain again and so I started college with Pre-Calculus being one of the first classes that I took. I fell in love with math; I chose math for my college major. How did that happen?

I am the only person I know who has had this change of heart regarding math. Everybody else, minus my sons who are 6 and 8 years old, that I work or socialize with still dislikes math. Even the vast majority of people I know, who graduated from the U.S. Air Force Academy, a foremost institution of STEM (Science, Technology, Engineering, and Mathematics) programs, were not STEM majors. Why is there such a lack of interest among students in math and other STEM areas?

The overarching issue is understanding. The majority of students hit a wall in mathematics where they need more time than they are given to understand the subject matter. They begin to fall behind, are unable to catch up, and so they come to dislike it and give up. The school system pushes the students along to the next grade and, already behind, the cycle continues until math is looked upon as something to get away from as soon as possible. The data bears out this lack of aptitude and fortitude. According to the 2013 National Assessment of Educational Progress (NAEP) only 26% of 12th grade students are rated as at least proficient in

mathematics which is similar to the number here in Colorado, which is 33% (Asp, Pearson, & Zurkowski, 2014), and my school, which is 20% (Hamm, 2014). According to the National Math and Science Initiative, only 44% of high school graduates are considered "ready for college-level math." Once in college the numbers do not get much better. The National Center for Educational Statistics, on behalf of the U.S. Department of Education, states that only 28% of students pursuing a bachelor's degree are pursuing one in a STEM subject, 2-3% for math specifically (Chen & Soldner, 2013). And of those that begin with a STEM major, 48% leave the STEM subjects or college altogether (Chen & Soldner, 2013). In the increasingly technological age which we live, the need for mathematics, as a basis for other STEM subjects (if not for its own sake), has never been more important.

It is the job of educators to improve the lot of mathematics in the eyes of our students. A great teacher can make any subject understandable and, dare I say it, fun. That is what converted me. The teacher I had for that Pre-Calculus class completely changed how I viewed math. Where once I didn't understand areas and disliked the areas I did understand, I came to view math as an intriguing and beautiful puzzle to be solved. Where once I had no interest, I could no longer search enough. That is what drew me to the education profession- to see others have that "ah-ha" moment.

Now what intrigues me is the idea of using flipped instruction for the mathematics classroom. In its simplest concept, having a flipped classroom "means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" (Lage, Platt, & Treglia, 2010, p. 32). Could that help improve students understanding of math and eliminate the barrier that causes so many to give up? Might it make math interesting enough to allow students who hit that barrier to push through it and persevere because they *want*

to see what comes next? I don't know but that is part of what I will attempt to study. Therefore, the purpose of this project is to answer the following research questions:

1) What is the effect of a flipped mathematics classroom on students' end-of-chapter test scores?

And, as a sub-question:

2) What are student's impressions regarding the use of flipped instruction in the mathematics classroom?

While the diversity of human interests means that it would be impossible to captivate everybody with math, there must be more people who *could* like it. Those mathematicians, scientists and engineers who have slipped through the cracks are the ones that must be engaged in order for America to continue to compete in the global market.

Literature Review

The flipped classroom experiment begins with the student's review of material at home, in this case using video podcasts, or vodcasts, to deliver the information. Vodcasts are audio/visual files that are available on the internet for personal viewing via web based classroom management sites like Blackboard or public sites such as YouTube or Vimeo (McGarr, 2009). The effects of using flipped instruction on student knowledge (qualitatively) and quiz/test scores (quantitatively) is the focus of this literature review.

While quiz/test scores are important, internalized subject knowledge may be more useful in the long run. Regarding the effect of flipped instruction on student knowledge, three main aspects emerged from the literature review: (a) the coverage of the class material in flipped classrooms, (b) the effectiveness of the vodcasts themselves as teaching tools, and (c) the ability of flipped instruction to prepare students for the real world.

Coverage of Course Content in Flipped Classrooms

One concern with flipped classes is that it may take more time to cover material since teacher interaction in class is often one on one or in small groups. This line of reasoning states that the instructor must teach the same material numerous times to the different individuals or groups versus the singular lecture of a traditional classroom. While part of the problem with that idea is the misconstrued concept of how the flipped classroom works, the data also does not bear this conclusion out as multiple studies concluded that coverage of material does not suffer in the inverted classroom. Lage et al. (2010) used vodcasts as part of the flipped instruction of a semester long university micro-economics class. McGivney-Burelle and Xue (2013) used vodcasts to flip a single unit during the semester of a Calculus II class. Both studies concluded that the instructors were able to cover the same amount of material in the flipped class as they were in a traditional class.

Mason, Shuman, and Cook (2013) studied the effect of using flipped instruction for a semester on a university upper division engineering course by comparing it to the same class taught traditionally during a different semester. That study concluded that the flipped class was able to complete more content during the semester than did the traditional class.

These studies show that by choosing to utilize flipped instruction, the class may benefit from being able to complete more material than they otherwise would be able to during a traditional class, or at least, that the students subjected to flipped instruction will not be adversely affected when it comes to content coverage. Ensuring that the requisite material is covered is an important aspect towards ensuring that student knowledge can be attained.

Vodcasts as Effective Teaching Tools

The next theme that arose regarding flipped instruction's effect on student knowledge dealt with the effectiveness of vodcasts as educational tools. McGarr (2009) states that the effectiveness of vodcasts as teaching tools can be divided into three areas: flexibility, accessibility and learning, which I will refer to as usability. Flexibility deals with the idea that, by their nature, vodcasts cater to multiple student learning styles. Auditory learners have narration; visual learners have slides or animations. The combination of the two makes the vodcast a useful tool to a wide variety of learners. Accessibility deals with the idea that the material can be accessed from anywhere. The material may be streamed while sitting at a computer at home or downloaded to a mobile device for viewing while on the go. Usability deals with how useful the vodcast is in the context of the class. In addition to their use in introducing content, vodcasts can be watched again as part of study review for a test or to refresh one's memory on how to solve a certain type of problem.

Multiple studies noted the effectiveness of vodcasts as teaching tools. Kay and Kletskin (2012) gave a series of vodcasts featuring worked examples of Pre-Calculus and Trigonometry problems to students at the start of a Calculus I class. The students were to be tested on their knowledge of those areas prior to starting Calculus I work. The students were able to use the vodcasts to study for the test but were not required to. Almost ninety percent of the students rated the vodcasts as either a useful or very useful tool for their studies. Common responses by students who rated vodcasts positively noted their flexibility and accessibility.

Similar results were also noted in the studies conducted by McGivney-Burelle and Xue (2013) and Lage et al. (2010) as well as O'Bannon, Lubke, Beard and Britt (2011). O'Bannon et al. used vodcasts to replace lectures in a core technology class used for pre-service teachers. While the aspects of flexibility and accessibility were noted in all three studies, usability was not.

Students in the O'Bannon et al. (2011) study questioned the usability of the vodcasts as they could see and hear the same exact material in class. This view can be attributed to the fact that the vodcasts used were the recorded lectures and slides used by the teacher in the traditional classroom section; the only difference between the two groups was the medium and the students liked having the instructor around to elaborate on ideas.

Another negative reaction to vodcast usage was found in the study by Lape et al. (2014) where vodcasts were used by a group of engineering and differential equations students for part of a semester. The main issues, though, seemed to have to do mainly with the quality of the vodcasts (poor audio and hard to follow graphics) and the fact that the students did not want to put in the time to view them outside of class.

Together, these studies show that the use of well-crafted vodcasts that are easily accessible, contain clear examples with elaboration, and are available throughout the course for a student to revisit are useful tools for learning in a flipped classroom of such type that will be used for my study.

Connections to Real World Skills

The third aspect regarding the effect of flipped instruction on student knowledge levels centered on the idea of flipped instruction preparing students for what is expected of them in the world outside of academia. The three practical skills that came up in this area were taking personal responsibility (for preparing for class in this case), working collaboratively, and having positive, useful interactions with superiors (teachers, in the case of school). Positive reviews regarding the increased ability to interact one on one with the teacher and to receive instant feedback from the teacher when flipped instruction was used were noted in two studies (Lage et al., 2010; McGivney-Burelle & Xue, 2013). The ability to practice working collaboratively with

others during a flipped class was lauded in studies by Lage et al. (2010) and Mason et al. (2013). The attitude of school as preparation for life is best summed up in the study from Mason et al. (2013) which states that "a student's ability to accept personal responsibility for learning is an essential part of intellectual development and preparation" (p. 434). The need to take responsibility for one's learning in a flipped instruction course is a notion that is seconded by Lage et al. (2010) and, in a backward way, by the student's dislike of having to do more than come to class set to receive information as cited in Lape et al. (2014). Another study using flipped instruction over three different lengths of time was undertaken by Talbert (2014). In a linear algebra class, he first flipped one portion of one unit, then used flipped instruction for various workshops throughout a semester, and, finally, for one whole semester. Like the above studies, students felt that the responsibility to undertake the preparation required in a flipped classroom helped prepare them for the real world.

These studies help show the benefits of using flipped instruction on student knowledge that goes beyond simple school instruction and subject literacy. While they still fall under the heading of student knowledge, these abilities also cross into the realm of useful day to day skills that will serve students long after they have left the classroom. As long as students are given a clear idea of what to expect in terms of preparation for participating in a flipped classroom environment, the method appears to be successful in this area.

Effect on Students' Subject Matter Knowledge

Effect on general student knowledge. Along with the previous subsets of student knowledge, there is also literature regarding the overarching question of the effect of flipped instruction on the student's level of subject knowledge; or put another way, whether test scores were affected or not, did students feel as though their knowledge level was affected. A study

conducted by Crippen and Earl (2004) compared two semesters of a university introductory chemistry class. The first semester was taught traditionally with in-class quizzes. The version of flipped instruction in this study was take home quizzes that showed worked out examples along with the quiz questions; students could watch the solving of an example problem that was similar to the quiz question that was to be asked. The results found that student's felt their knowledge level increased with the flipped quizzes as they were able to apply the techniques learned from the examples to the quiz questions and future assignments. Similar results were noted in other studies as well (Kay & Kletskin, 2012; Lage et al., 2010).

In the study by Lape et al. (2014), the results were similar to the above findings for the engineering class but not for the differential equations class. This was most likely due to the fact that the traditionally taught math class also had access to the vodcasts used for the flipped class essentially giving those students extra help. Due to this, the knowledge level of students in the traditional class was increased while the flipped class did not feel the method of instruction helped their knowledge levels.

Effect on students' test scores. In today's world of No Child Left Behind, tests are still as important as ever, meaning that any kind of non-traditional instruction must still prepare students to perform on quizzes and tests at the local, state and national levels. Flipped instruction may be up to bettering the performance of that task.

I did not encounter any studies which indicated that using flipped instruction had a negative effect on any aspect of student test, quiz, or homework scores. This is an important point because teachers cannot do anything which might harm student's learning, and students are under enough pressure without having to be subjected to a new form of instruction with a detrimental track record. I encountered two studies which showed that utilizing flipped

instruction had no significant effect on student scoring (O'Bannon et al., 2011; Lape et al., 2014). However, as noted before, this could be due to the fact that both of those studies did not fully implement or separate the flipped instruction from the direct instruction. O'Bannon et al. (2011) simply used vodcasts that were exactly the same as what the direct instruction class had, and Lape et al. (2014) allowed the students in the direct instruction class to use the flipped instruction section's vodcasts as additional resources for their betterment. In one case there was no real difference between the flipped and direct classes and, in the other, the direct instruction class was advantaged by having the resources of the flipped class as well.

There were also three studies which I encountered that showed a positive effect on student scores (McGivney-Burelle & Xue, 2013; Mason et al., 2013; Crippen & Earl, 2004). The important fact regarding this result from these studies is that all three studies were varied in many ways. All three studies involved different STEM subjects, using slightly different implementations of inverted instruction, for differing lengths of time. The positive outcome from flipped instruction despite the variance in these studies is telling in that it shows how, when done correctly, the flipped method will probably improve student quiz and test scores which, while not the sole measure, is certainly an important measure of student knowledge gains.

Summary

Altogether, these studies help inform the decision to study the use of flipped instruction and its effect on student's knowledge and test scores. The literature seems to show that, regarding flipped instruction when it comes to covering the content of a course, the coverage using flipped instruction is comparable to, if not better than, direct instruction, meaning that students will not be disadvantaged by receiving flipped instruction. The literature also shows that vodcasts, such as those that I plan on using, are effective tools for instruction. They are

flexible enough to be used by people with many different learning styles. They are able to be accessed from any internet connection for immediate viewing or for storage, allowing students to view them when they are able. They are usable beyond the simple introduction of material, either for study or for reference. Flipped instruction also goes beyond the schoolhouse and extends important life skills to students such as taking responsibility, working collaboratively and interacting positively with superiors. While this qualitative knowledge is important, today's world still values grades. The literature supports utilizing flipped instruction as a possible course of action for helping to increase test scores as many of the reviewed studies showed either no effect on scores (at the least meaning there is no detriment) or even a positive effect on scores. This all points to the theory stating that, when done correctly; flipped instruction will help increase student knowledge and increase student scores on chapter tests and quizzes.

Description of Research Context

This action research project will take place during the 2015-2016 school year at Sand Creek High School, a suburban, public high school located in Colorado Springs, CO. Sand Creek has 1175 students in grades 9-12 and is an IB program school. Sand Creek has been open for 18 years therefore, while it is fairly new and is well kept; it is beginning to show some early signs of aging. One reason for this is that the school is also growing fast- more than 80 percent of the growth of Colorado Springs school enrollment has been absorbed by District 49, of which Sand Creek is a part. Despite this growth, the average class size is around 20 students per teacher (which is the number I'll go with).

The school is split virtually 50/50 gender wise and is located in a mostly middle class area (27 percent of students qualify for free or reduced price lunches). The ethnic split is 56% Caucasian/20% Hispanic/12% Black/6% Asian/6% other. Approximately 30 percent of the

students come from military families which brings some unique challenges like showing up in the middle of the school year and not having an established social network for support. The area has a mix of conservative (military and military retirees mostly) and liberal (it's Colorado) views; education and schools are highly valued but the methods used for assessment are a constant battle. The United States Air Force Academy is also located in town which motivates many local students to achieve academic excellence (especially in STEM subjects) in order to attend it.

The classes chosen for this project are two different Pre-Calculus classes composed of 16-18 year old students in their junior or senior year. Pre-Calculus was chosen due to the mix of year groups in the class hopefully making the results more generalizable. Some are juniors taking the class in order to take AP Calculus as seniors; some are seniors terminating the usual progression of math classes for the college-prep (non-IB, non-AP) track. None of the students have known learning disabilities however, the percent of sophomores rated as at least proficient in math (and hence a percentage of those entering this class) on the Transitional Colorado Assessment Program (TCAP) is only around 20 percent (Hamm, 2014). This indicates that many of the students in these classes may not be ready for them and may require remedial instruction during the first weeks. In order to participate in the project, the students will need their textbook and a computer with internet access. If a student does not have computer/internet access at home, the school library has computers which are available for use.

Study Methods

The research questions seeking answers in this study deal with the effect of flipped instruction on the quiz scores, test scores, and subjective knowledge of 11th and 12th grade

students in a semester long Pre-Calculus class. What does the day to day structure of that classroom look like?

Instructional Methods

The direct method of instruction is the current way that most classes are taught. For direct instruction, the general sequence of events in class each day begins with a quiz (if given) followed by a teacher lecture covering the day's material and featuring the teacher working example problems on the whiteboard in front of the entire class with some student input. At the end of class, homework featuring a series of problems relevant to the day's material will be assigned to be completed and turned in the following day. The first half of the semester (three chapters) will be taught using direct instruction.

The sequence of events in the flipped classroom will begin with a quiz (if given) followed by individuals or groups (depending on the activity) working of a series of problems relating to the material covered in the previous day's vodcast. While the students are working these problems, the teacher will move amongst the students to ensure the material is being understood and will only address the class as a whole to explain areas where many students are encountering difficulty or to counter any misconceptions that may have formed. At the end of the class, the students will be assigned the vodcasts to view for the next day. The second half of the semester (three chapters) will be taught using flipped instruction.

Data Sources

The main source of quantitative data will come from teacher administered quizzes and tests. These quizzes and tests will be standard math tests with a series of problems to be worked out and answered by the student. Point values will be assigned based on the amount of work shown and the correct answer being found. Quizzes and tests will be given in order to measure

student knowledge of the chapter's material and assess if there is an effect on quiz and test scores when flipped instruction is used. Quizzes will be given to the students at the beginning of class at least twice per chapter and more often if the subject matter warrants it. At the end of each chapter students will be given a test in class covering the material from that chapter only though, since mathematics is a building block subject, as the class progresses, ideas and mechanics from previous chapters may be needed to help answer later test questions.

The qualitative data for this project will come mainly from a student questionnaire (attached as Appendix A). The questionnaire will allow students to express their opinion regarding subject matter understanding and retention when using flipped instruction. The questionnaire will be handed out two weeks before the end of the semester with the instruction to turn it in no later than the beginning of the last week of the semester before winter break. At the beginning of the last week of the semester I will make an initial examination of the questionnaires. If I find any responses which bring up additional questions I might have or that I need to have clarified then I will conduct a personal interview with that student during the last week. This will allow the student to expand upon his/her answers ensuring that the correct conclusion is being evaluated and that any new issues or concerns are noted. Information which may be useful for bettering the execution or expanding the scope of the next iteration of this project may also be wrought from the questionnaire or ensuing interview.

Data Analysis

The results of this project will be analyzed based on two main factors: the quiz/test scores of the students as well as the student's opinions as reflected on the given questionnaire. Graphics depicting the results of the data analysis can be found in Appendix B.

All student quiz and test scores (along with homework grades from the direct instruction portion of the class) will be recorded in an electronic grade book. At the end of the semester, students will receive a letter grade on the standard A-F scale consistent with the standard percentage scale for that grade (A= %100-90, B=%89-80, C=%79-70, D=%69-60, F=%59-0). Student grades for this semester will be compared with the grades received in the student's previous mathematics classes which will be obtained through the school's transcript database. Whenever possible, previous teachers will also be contacted to find out whether any form of instruction other than direct instruction was used.

While comparison between different semester's grades may be useful, the factors involved are far too complex to specifically pin down the cause of any effect to half of a semester of flipped instruction. For example, students who are motivated to get good grades are likely to be motivated to attain high levels of achievement no matter the form of instruction used. Therefore, the effect of the form of instruction will be compared within our classroom as well. Within the context of our classroom, quiz and test scores attained by each student while receiving direct instruction will be compared with that same student's scores attained while receiving flipped instruction. While it will not establish a direct relationship, comparing a student to himself/herself should lessen the influence of outside factors, helping to narrow the cause of any effect on scores to the type of instruction received.

The final comparison on any effects of the flipped method will be taken from the student's responses on the questionnaire. As mentioned above, scores may or may not be affected by the different instruction types so student's opinions will be analyzed as well. Student responses indicating that one method of instruction helped to internalize the subject matter knowledge better than the other will be the main focus of examination of the questionnaire.

Questions regarding time spent studying while receiving each instructional method and which approach student's liked better will be used to help identify other factors that could correlate to student achievement. For example, a student may have done better with one method because they spent more time studying during that method's use rather than because the instruction method itself was superior. Identifying any of these possible correlations will help to ascertain any effect the instructional method itself had on student achievement.

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Appendix A

Student Questionnaire on Mathematics Instruction

Please complete this short questionnaire regarding the two types of instruction you received during our Pre-Calculus class. Please elaborate as much as you can; I may ask you for details regarding your responses at a later date. Thank you for your participation in this project!

As a reminder, the general daily sequence of events for each instructional method was:

Direct Instruction: Quiz (if given), Teacher lecture w/example problems, homework given for at-home completion/next day turn-in

Flipped Instruction: Quiz (if given), Group work on problems (w/teacher intervention/discussion as needed), vodcast(s) given for at-home viewing

1. Approximately how much time did you spend studying math each night while receiving direct instruction? With flipped instruction?

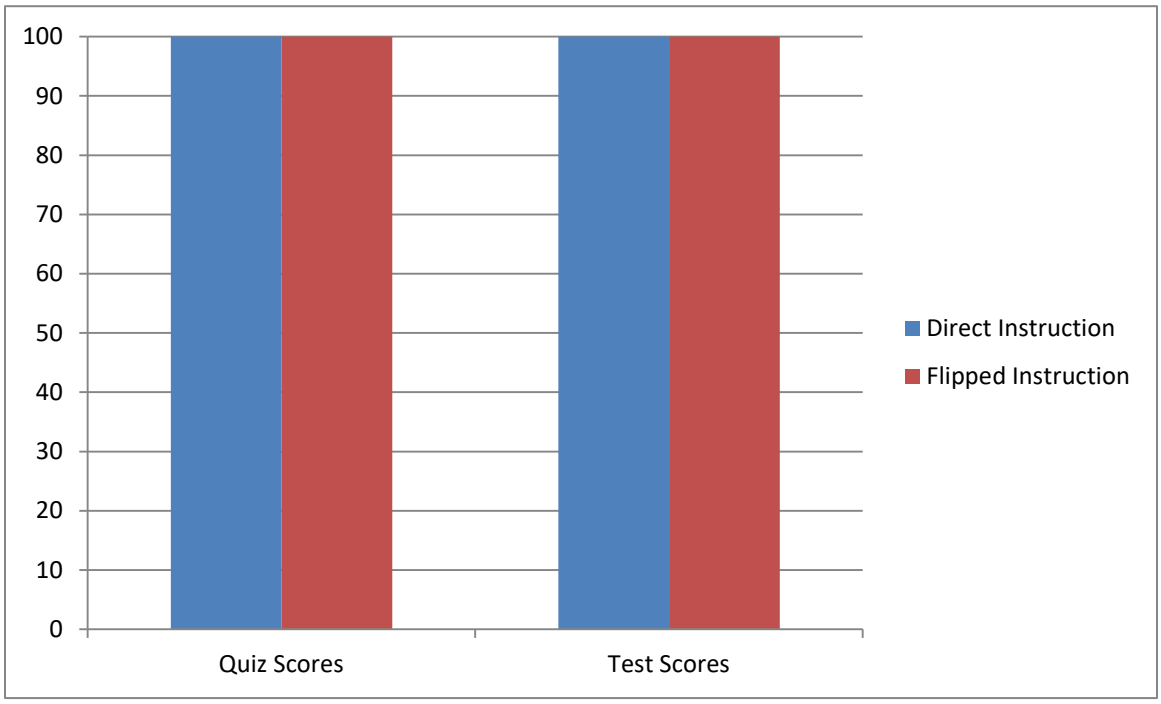
2. Did one type of instruction help you understand and/or retain the material better than the other type? If so, which type helped you more, and why?

3. Which of the two types of instruction (direct or flipped) did you prefer? Why?

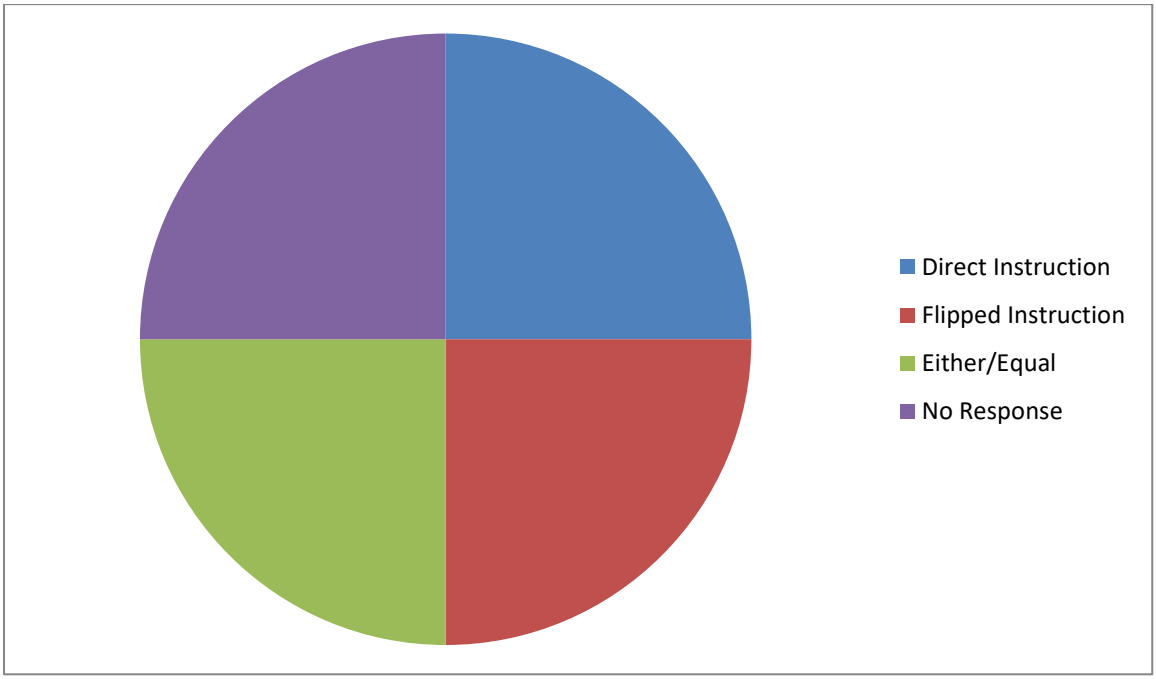
4. Regarding your experience with the two types of instruction, please list any additional comments you may have here:

Appendix B

Average Quiz and Test Scores



Student Identification of More Helpful Approach to Instruction



Appendix B

Student Preference of Instructional Method