Using the ARCS Model to Influence Students' Attitudes Toward Geometry

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Abstract

Attitude toward mathematics learning is one of the essential components for successfully completing mathematics courses. Research indicates many students hold negative views of mathematics. This inquiry aims to determine the effects of the ARCS model and the software IXL on students' attitudes toward geometry learning. This classroom research uses a mixed method design to ascertain the students' attitudes before and after the course. The quantitative data revealed that a significant number of students started the course with negative views of mathematics learning and the treatment had no statistically significant effect, while the categorical data analysis showed a positive shift in attitude.

Keywords: students' attitudes toward mathematics, mathematics teaching and learning, real-world application of geometry, instructional videos in geometry, ARCS model of learning, motivation to learn mathematics

Introduction

I have been teaching undergraduate mathematics for more than twenty years. Currently, I teach geometry honors to high school students at a developmental research school. Before joining the faculty there, I taught geometry and dual enrollment mathematics courses such as college algebra and introductory statistics for three years at a high school in Florida. Prior to becoming a high school mathematics teacher, I taught courses ranging from developmental mathematics to calculus for over 15 years at colleges in Florida.

Often, I would hear students lament about their difficulties with mathematics and describe their hatred of the subject. In addition, many students would ask me about the relevance of mathematics to their everyday lives or future careers (Matthews, 2018). Once, a student asked me, "Have you always loved math?" I responded honestly; I have not always loved mathematics. My fondness for the subject started around age 16, right after I lost my biological father. I credit a young math teacher who lived in my neighborhood for this shift in attitude toward mathematics learning. He invited a few young kids in the neighborhood to study mathematics every Saturday and Sunday afternoon. He served snacks and sodas, which gave the kids an incentive to participate. Once I started getting good at math, I started believing that my dream of becoming an engineer was possible. Further, when I started getting recognition in school as one of the top mathematics students, I was hooked because I took pride in being good at a subject many students dreaded.

Throughout my career, I have wondered how to make mathematics appeal to students who find the subject challenging. I subscribe to the belief that almost anyone can learn mathematics provided they have the proper foundation. Most of the time, students lose interest in learning mathematics between middle school and high school, and they continue to believe that a solid grasp of the subject is out of their reach well into adulthood. The immediate consequence of this belief is that these individuals avoid any careers that require a solid foundation in mathematics.

Many lucrative professions demand a solid foundation in mathematics; even technical careers that do not require training in upper-level mathematics still necessitate a solid foundation in basic mathematics. Yet, many high school students lack the motivation to learn mathematics and display a negative attitude toward the subject. This study aims to determine whether the insertion of videos showing real-world applications of geometry concepts influences students' attitudes toward the subject (Hodges & Kim, 2013). In addition, this action research seeks to ascertain the impact of the other instructional strategies used in the course on students' attitudes toward geometry learning. The following questions will guide this inquiry:

1. How does the insertion of videos depicting applications of geometry in the real world affect students' attitudes toward the subject?
2. What other instructional strategies impact students' attitudes toward mathematics learning in a geometry course?

Literature Review

A substantial number of students view mathematics as a dull, pointless subject. Many of these students lack the motivation to put forth the effort required to develop the necessary skills to become proficient in the subject. The literature suggests a strong connection between students' attitudes and achievement in mathematics (Asante, 2012; Farooq & Shah, 2008). Many studies have been conducted to identify the factors affecting students' attitudes toward mathematics learning. Davadas and Lay (2020) found positive correlations between parental influences, teacher support, classroom instruction, and previous achievement with students' attitudes toward mathematics. Tahar et al. (2010) identified some criteria that influenced students' attitudes toward mathematics: interest in the subject, self-efficacy, and self-concept.

Hodges and Kim (2013) conducted a study using Keller's (1987) Attention, Relevance, Confidence, Satisfaction (ARCS) motivational design to develop a video intended to teach a concept in college algebra. Through a pretest-posttest control group design, the study found a statistically significant difference between the treatment and the control group. Several studies have been conducted to test the effectiveness of the ARCS model of motivation on various aspects of the learning process. One study suggests a positive effect of the ARCS model on students' mathematical critical thinking ability (Suherman et al., 2021). Another study shows that when teachers consistently show the relevance of mathematical concepts to the real world, students' valuing of the subject improves (Matthews, 2018). The current study seeks to ascertain whether the insertion of carefully chosen videos depicting real-world applications of geometry affects students' attitudes toward the subject.

Course Description

The geometry course is intended to develop the students' geometric concepts, skills, and processes that can be used to solve a variety of real-world and mathematical problems. The content of this course uses Algebra I concepts learned in previous courses to allow the students to develop strong critical thinking skills through the application of both algebraic and geometric concepts. The curriculum includes the following topics: points, lines, planes, angles, proofs involving inductive and deductive reasoning, basic trigonometry, and the study of various geometric shapes, both two and three-dimensional (P.K. Yonge, n.d.).

Course Design

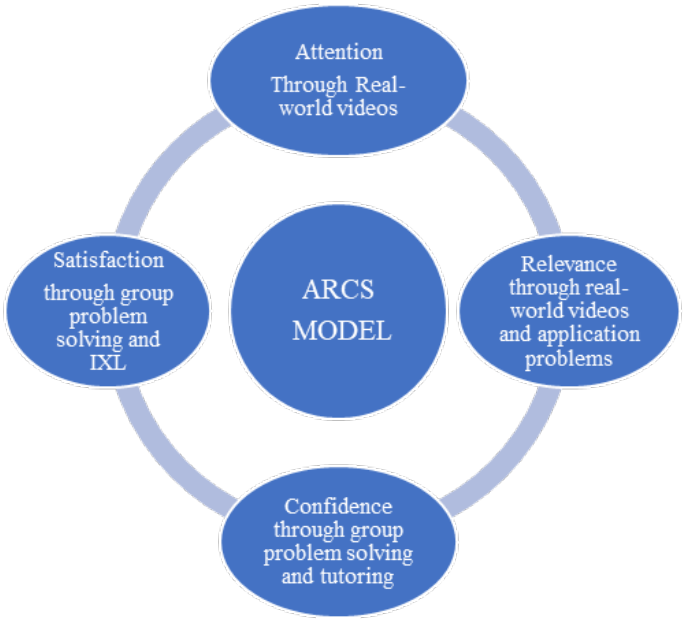
I applied the ARCS model for instruction (Keller, 1987). To draw students' "Attention" and emphasize the "Relevance" of the topics, during the first half of the semester, I started every lesson with a warmup; the warmups consisted of showing a video depicting real-world applications of the geometric concept under consideration to the class; then I directed the students to respond to a few prompts related to the videos via the Learning Management System (LMS). After the warmups, I led

an exposition of the lesson that included questioning to gauge the students' understanding of the material. The direct instruction phase took no more than 30 minutes and was followed by practice sessions where students worked in groups of at most five to solve problems directly related to the concepts covered during the lesson. During practice time, I went around the classroom to provide scaffolding or asked the students to come up to my desk to ask questions. At the end of the practice session, if time permitted, I allowed the students to start their homework assignments in the classroom and finish them at home later that evening (Keller, 1987; Lee & Kim, 2012).

To address the "Confidence and Satisfaction" components of the model, I required the students to complete the homework assignments using the web-based software "IXL." IXL is an adaptive program that presents problems to the students, and they must supply the answers online (Li & Keller, 2018). If the answer is correct, the program celebrates the students' accomplishments by awarding points and displaying words of encouragement on the screen; if the answer is incorrect, the program informs the students and displays the solution step by step and takes away a few points from the students' total score (IXL, n.d.). For exam reviews, I put the students in groups that rotated to different stations to discuss strategies to solve the problems presented at each station. Also, I used the web-based software "Kahoot" at various times to conduct quizzes and exam reviews.

In addition, I partnered with the coordinator of the National Honor Society, to provide tutoring and mentoring to struggling students twice per week for one hour after school. The coordinator recruited students who successfully completed the course to serve as tutors. At the beginning of the semester, I administered a pre-test to all students designed to gauge the students' basic algebraic skills. I used the pre-test data, the results of the students' performance on the Florida State Assessments (FSA) for Algebra I, and the students' performance on the first quiz to select the students who would be invited to participate as tutees in the after-school program. After making the selections, I informed the parents by sending a letter home with the students and I followed up with a phone call or email.

Figure 1. *The ARCS Model Course Design for Geometry*



Methodology

Instrument and Participants

I used a mixed-method research design during the Spring 2022 semester. The participants consisted of students enrolled in a geometry course. The participants consisted mostly of ninth graders with a few 10^{th}, 11^{th}, and 12^{th} graders. Of the 74 students enrolled in the course, 60 completed a modified version of the Attitudes Towards Mathematics Inventory (ATMI) at the beginning of the semester, and 61 students completed the same survey toward the end of the semester. The survey consisted of four subscales: self-confidence, value, enjoyment, and motivation (Ngurah & Lynch, 2013). I removed nine from the original 40 items that comprised the original survey because I felt those nine items were more suited for college students, and I used the remaining 31 Likert-type items to establish the students' attitudes toward mathematics before and after completion of the course. Students' responses ranged from 1 (*strongly disagree*) to 5 (*strongly agree*). After aggregating the data for each subscale, I conducted some statistical analyses which included descriptive statistics and a paired sample *t*-test to determine whether a statistically significant difference emerged between the students' responses before entry and after completion of the course. Tables 1, 2, 3, and 4 below present a description of the items included in the survey as well as the results for each subscale; Table 5 provides the results of the paired sample *t*-test.

Qualitative Data

To ascertain the impact of the instructional strategies on students' attitudes toward geometry learning, I selected six students for an interview about two weeks before the end of the semester. I made the selections based on the students' overall grades in the course up to the date the students received the invitation to take part in the interview; two students were from the top ten percent of the class, two were from the middle twenty percent, and two were from the bottom 20 percent. Some interviews took place in the classroom, and the students' responses were recorded and then transcribed. Other participants submitted written responses by replying to the email I sent to them with the survey items because either the recordings were unintelligible or there was no convenient time to complete the interview in person. The interview protocol is included in the appendix.

To address the research questions, I reviewed the students' responses to the questions listed in the appendix. In particular, I looked for the following: (1) The interviewees' specific mention of any of the videos presented during the semester and how it affected their views toward geometry learning, (2) The interviewees' perception of the instructional strategies deployed in the course and whether they found them helpful in learning the material, and (3) the interviewees' views regarding the instructional activities included in the course. To analyze the data, I highlighted specific sentences that addressed the interview questions and copied the sentences onto sticky notes. Then, I placed the sticky notes on a whiteboard and drew connected lines to uncover patterns and trends.

Results

A review of Tables 1, 2, 3, and 4 reveals an increase in the percentage of students who provided a positive response to several items from the survey. Table 1 describes the changes in confidence from the beginning to the end of the semester. Items 2, 4, 6, 7, 8, and 11 show an increase in confidence. The percentage of students reporting they could not think clearly while working with mathematics or felt uncomfortable about mathematics decreased, while the percentage of students who reported feeling self-confident about their mathematical abilities increased sharply. Contrastingly, Items 1, 3, 5, 9, and 10 reveal a negative shift in attitude. The proportion of students who felt that mathematics is one of their most dreaded subjects increased significantly. In addition, the percentage of students who

were nervous and disliked the subject increased. And the percentage of respondents who reported feeling they could do well in mathematics decreased.

In Table 2, item 12, the percentage of students who agreed or strongly agreed that mathematics is a worthwhile and necessary subject increased slightly while there was a decrease in items 13 through 18. In Table 3, item 20 shows a noteworthy decrease in the proportion of students who find mathematics dull and boring, while the decrease in item 19 and items 21 through 27 indicated that more students saw no value in learning geometry. In Table 4, items 28 to 31, the percentage of students motivated to pursue further studies in mathematics decreased. Table 5 describes the results of the paired sample *t*-test for each subscale. There was no statistically significant change in the means for confidence, enjoyment, and motivation. However, the mean for the value subscale increased significantly ($p<0.05$).

Table 1. *Survey Results for Confidence*

Item	Item Description	Percentage of Agree/Strongly Agree		Percentage of Disagree/Strongly Disagree		Percentage of Neither Agree nor Disagree	
		Before	After	Before	After	Before	After
1	Mathematics is one of my most dreaded subjects.	41.6	50.9	16.7	29.6	26.7	19.7
2	My mind goes blank, and I am unable to think clearly when working with mathematics.	28.4	24.6**	26.7	39.4	30.0	36.1
3	Studying mathematics makes me feel nervous.	38.3	42.6	23.3	31.1	23.3	24.6
4	Mathematics makes me feel uncomfortable.	33.3	31.1**	40.0	37.7	25.0	31.1
5	When I hear the word “mathematics,” I have a feeling of dislike.	43.4	50.8	20.0	21.6	36.7	27.9
6	Mathematics does not scare me at all.	20.0	24.6**	46.7	41.0	33.3	34.4
7	I have a lot of self-confidence when it comes to mathematics.	10.0	18.1**	60.0	39.4	30.0	42.6
8	I am able to solve mathematics problems without too much difficulty.	18.4	27.8**	33.3	27.9	48.3	44.3
9	I expect to do fairly well in any mathematics class I take.	43.4	31.1	16.7	27.9	38.3	41.0
10	I learn mathematics easily.	18.3	19.6	33.3	49.2	48.3	31.1
11	I believe I am good at solving mathematics problems.	16.7	27.9**	35.0	24.6	48.3	47.5

** *Indicates a positive shift in confidence ($p<0.05$)*

Table 2. *Survey Results for Value*

Item	Item Description	Percentage of Agree/Strongly Agree		Percentage of Disagree/Strongly Disagree		Percentage of Neither Agree nor Disagree	
		Before	After	Before	After	Before	After
12	Mathematics is a very worthwhile and necessary subject	43.3	44.2	6.7	14.8	50.0	41.0
13	I want to develop my mathematical skills.	80.0	64.0	18.3	6.5	1.7	29.5
14	Mathematics helps develop the mind and teaches a person to think.	60.0	54.1	5.0	13.1	35.0	32.8
15	Mathematics is important in everyday life.	48.3	44.3	18.4	21.4	33.3	34.4
16	Mathematics is one of the most important subjects to study.	56.7	36.1	20.0	23.0	23.3	41.0
17	High school mathematics courses would be very helpful no matter what I decide to study.	41.7	36.1	15.0	19.7	43.3	41.0
18	I can think of many ways that I use mathematics outside of school.	40.0	34.4	31.7	22.9	28.3	42.6

Table 3. *Survey Results for Enjoyment*

Item	Item Description	Percentage of Agree/Strongly Agree		Percentage of Disagree/Strongly Disagree		Percentage of Neither Agree nor Disagree	
		Before	After	Before	After	Before	After
19	I have usually enjoyed studying mathematics in school.	21.7	21.3	45.0	45.9	33.3	32.8
20	Mathematics is dull and boring.	48.3	44.3**	21.7	16.4	30.0	39.3
21	I like to solve new problems in mathematics.	21.7	19.6	31.6	39.4	46.7	41.0
22	I would prefer to do an assignment in mathematics than to write an essay.	40.0	31.1	40.0	49.2	20.0	19.7
23	I really like mathematics.	15.0	14.8	50.0	50.9	35.0	34.4
24	I am happier in a mathematics class than in any other class.	5.0	0.0	76.7	75.4	18.3	24.6
25	Mathematics is a very interesting subject.	38.3	24.6	35.0	31.2	26.7	44.3
26	I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in mathematics.	23.4	24.6	36.7	36.1	40.0	39.3
27	I am comfortable answering questions in mathematics class.	15.0	13.1	48.4	39.3	36.7	47.5

** *Indicates a positive shift in attitude ($p < 0.05$).*

Table 4. *Survey Results for Motivation*

Item	Item Description	Percentage of Agree/Strongly Agree		Percentage of Disagree/Strongly Disagree		Percentage of Neither Agree nor Disagree	
		Before	After	Before	After	Before	After
28	I am confident that I could learn advanced mathematics.	33.3	23	36.7	31.2	30.0	45.9
29	I would like to avoid using mathematics after high school.	31.7	32.8	25.0	23.0	41.7	44.3
30	I am willing to take more than the required mathematics.	21.7	19.6	45.0	45.9	33.3	34.4
31	I plan to take as much mathematics as I can during my education.	28.3	8.2	41.7	44.2	30.0	47.5

Table 5. *Results of Paired Sample t-test*

Subscale Description	Mean		*p*-value
	Before	After	
Confidence	32.8	32.4	0.6
Value	24.0	22.6	0.03*
Enjoyment	24.6	23.7	0.19
Motivation	11.4	11.1	0.48

**Statistically significant at the 0.05 level.*

Interview Results

Participant 1

Becky is a white female student who was at the top of the class. She completed all the assignments in the course and performed extremely well on all the tests and quizzes. Because she was wearing a mask at the time of the interview, I could not understand her responses on the recording, I sent her the questions via email, and she responded by replying to the email. Becky felt that all activities in the course were helpful and enjoyed the Kahoot activities. Becky specifically remembered the "building in the sky video" presented at the beginning of the semester and said that, as she is planning to become an architect this video had the most effect on her and made her realize the connection between architecture and geometry.

Becky described putting a significant amount of effort into the course and would advise future students to make sure to keep up with all the assignments in the course. Becky's score for confidence decreased by two points, her score for value increased by one point, her score for enjoyment decreased by 1 point, and her motivation score remained the same.

Participant 2

Arma is a female student who identified as biracial. Arma completed all the assignments in the course, but her final grade was a "B" because her performance on tests and quizzes was not exceptional. Arma stated that the videos helped her gain a better understanding of the material and saw a relationship between the videos and the lessons. She enjoyed the group activities that involved rotating to different stations but expressed some reservations because there were no tables or chairs to

sit down and write at every station. Arma would have liked to see more videos and live demonstrations; she would advise future students "to study the proofs and to remember the rules for the shapes."

Arma did not answer some of the items for the confidence subscale, thus her entries were excluded from the analysis for that subscale. Arma's score for value decreased by 1 point, her score for enjoyment increased by 1 point, and her motivation score increased by 3 points.

Participant 3

Martino is a male student who self-reported as Hispanic. He earned a "B" in the course and reported that the portion of the class that involved direct instruction and notetaking helped him complete the class and homework assignments. However, he felt that too much time was spent on notetaking because it reduced the amount of time left for class practice. Martino liked receiving review packets before each assessment because they helped him study. He reported enjoying the IXL assignments at the beginning of the semester, but he disliked having to complete them starting around the middle until the end of the semester. He feels like they started to get repetitive and the amount of IXL assignments should be reduced in the future.

Martino stated that he did not see any connections between the videos and the lessons but felt like the videos introduced the lessons and the direct instruction portion of the lessons taught him how to solve the problems. He reported studying more for this course than others and would advise students in the future to study and prepare notecards before each assessment. Martino left some items involving the confidence subscale blank, and his entries were not included in the analysis; his scores for value and enjoyment decreased by 2 points, and his score for motivation increased by 1 point.

Participant 4

Jeffrey is an African-American male who was invited to participate in the after-school program. Jeffrey stated that coming to get help after school, the class practices, and the warmups helped him a lot. He reported that the IXL assignments are both helpful and unhelpful because sometimes he got frustrated when he answered a question incorrectly, and the software reduced his total score. Also, he enjoyed the group activities because they allowed him to interact with other students and allowed him to practice. He did not dislike any of the activities and felt like everything was helpful. He made connections between the videos and the lessons and was able to identify a specific video about a building he felt helped him with a concept studied in class. He stated that "the video allowed him to see that geometry is everywhere he goes and a cool thing to learn about."

However, Jeffrey said there were no changes concerning his views regarding learning geometry. He described having to put more effort into this course and more time because he had to come after school, when necessary, to become proficient in some topics and maintain a good grade. He would advise future students to study hard and seek help after school and would have liked longer hours after school because he participated in other activities. Jeffrey was not included in the statistical analyses because he did not complete the survey at the beginning of the semester. He earned a "C" in the course.

Participant 5

Howard is a white student with an Individualized Education Plan, he completed all assigned work and earned an "A" in the course. He was ambivalent about the class practices and would have liked to see this time used for direct instruction. He reported liking the Kahoot activities because he enjoyed the competitive aspects of those activities and felt like they served as good reviews for tests and quizzes. He hated the IXL assignments and felt like they were torture. He described being upset when the program reduced his total score whenever he answered a question incorrectly. Howard was able to

make connections between the videos and the lessons. Howard did not complete the survey at the beginning of the semester and was not included in the statistical analyses.

Participant 6

Michael, an African-American male student, failed the course. He did not complete most of the assignments, did not pass any of the assessments, and was either absent or late many times. Michael stated working in groups during class practices helped him because he was able to work with his peers. Michael disliked the IXL assignments that covered difficult topics and found them unhelpful. He would have liked to complete these assignments with me but stated that he never tried to seek help. He said that he liked the warmups because they were an easy grade, but he did not complete many of them because he came to class late, and he did not go back to complete them later even though they were available for at least another 24 hours via the LMS.

Michael stated that the videos revealed how geometry is used in real life and that mathematics is pervasive in real life. He recalled one video depicting how Pixar uses geometry to create and animate the cartoon characters in its movies but stated that this video did not change his views on geometry learning. Michael stated that he was never a good learner of math, and "laziness has come over him since the pandemic and he needs to refocus." He feels like he did not put in the necessary effort to be successful in this course. Michael feels like he is a hands-on learner, and more hands-on activities would have helped him, and it would have been necessary to keep going over the same concept until everyone gets it. He would advise students taking this course in the future to avoid falling behind, keep up with the homework assignments, and seek help as soon as challenges arise.

Discussion

The quantitative analyses yielded some mixed results. On one hand, the paired sample *t*-test (Table 5) shows no significant difference in students' attitudes toward confidence, enjoyment, and motivation ($p > 0.05$); and revealed a statistically significant negative shift in students' attitudes toward the value subscale ($p < 0.05$). These results may be due to the removal of some items from the original survey design; this may have affected the validity and reliability of the instrument. Another explanation may be that several students consistently came late to class, especially during the first period and the last period of the day which was right after lunch. Many of these students never watched the videos or completed the warmups even though these assignments were available after school via the LMS. Some research suggests that the application of the ARCS model resulted in statistically insignificant increases in attitudes, but it is still worth pursuing because of its significant effect on students' critical thinking abilities (Karakis et al., 2016; Suherman et al., 2021).

In addition**,** the results of the qualitative analysis imply that the respondents felt that they may have benefited from the activities and the overall course design. Three respondents reported enjoying the Kahoot activities, four reported that the videos allowed them to make connections between everyday life and the geometry lessons, and four enjoyed the group practices. These results indicate that the application of the ARCS model of instructional design is warranted in geometry. Further, an examination of the entries of four interviewees revealed a positive shift in motivation. This suggests using the ARCS model to design the course may have benefited several students, but some tweaks in instructional strategies are still necessary.

The data revealed that a sizeable proportion of students entered the geometry course with a negative attitude toward mathematics learning. Since most students were 9th graders, it is highly likely that many of the participants developed these negative attitudes before entering high school. Further, the students may have been developing these attitudes for years. The data revealed a need for an institutional will to address the issue of student attitudes before, during, and after high school. Improving students' attitudes toward mathematics learning should not be left to classroom teachers

alone as it is challenging to counter issues that students may have developed for years during one academic year, let alone one semester. Senior-level administrators could help by providing resources for student counseling, supporting after-school programs, and organizing events that highlight the beauty, value, and utility of mathematics to all stakeholders by inviting professionals who use mathematics in their daily work to speak to the school community.

Implications for the Future Instruction

Regardless of their standing in the course, a significant number of students disliked it when the IXL software reduced their total scores when they answered a question incorrectly. On average, the program reduces the student's scores by six points when they supply an incorrect answer. One interviewee suggested that the reduction in score should be fewer than six points. However, as the course instructor, I feel strongly that an adaptive system where the questions are randomly assigned is necessary to encourage the students to engage in productive struggle in mathematics. With the traditional paper-based homework assignments, many students copy off others without paying attention to the material. However, I plan to contact the company to explore whether it would be possible to allow teachers the flexibility to choose the number of penalty points for incorrect answers. Also, IXL shows students a step-by-step example before starting an assignment. I plan on reminding the students of this feature more often. Further, some of the videos were more impactful than others, I will keep searching for more inspiring videos that are culturally relevant to the diverse student body the school serves. Finally, I plan on attempting to increase students' enjoyment of the course by using more educational games as well as simulations and manipulatives.

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Appendix

Interview Protocol

Introduction

Good morning and thank you for assisting me with this interview. I value and appreciate your time. I am conducting a research study on students' perceptions of the instructional strategies I utilized in the geometry course. The purpose of this interview is to gather data regarding your perception of the activities in the course. Any information gathered will be held in the strictest confidence, and your name will not be used in any publication or presentation. In addition, this information will not be shared with anyone else including your parents. Finally, this interview will have absolutely no effect on your grade in the course.

Interview Questions

1. What activities or instructional strategies did you find helpful in the course?
2. What activities or instructional strategies did you find unhelpful?
3. Which tasks did you enjoy during the semester? Why?
4. Which tasks did you dislike? Why?
5. What connections did you see between the warm-up videos and what we were learning in class?
6. Describe a video that had an impact on you.
7. How did this video change your perception of the course?
8. Have there been any changes in your views regarding learning geometry? If yes, please describe those changes.
9. How much effort did you put into this course when compared to other courses?
10. What other activities that you feel might help students in the future?
11. What advice would you give students who will be taking this geometry course in the future?
12. Thinking of the course and the school, what else could have been done to help you master the material?

Closing

Thank you very much for your contribution to this research study. Your time is extremely valuable, and I thank you for allowing me to use it. Your contribution to this project is particularly important, and I cannot thank you enough for your assistance. If you have any questions or concerns, I would like to address them at this time, or if you prefer, it could be at a future date. And, if I have any questions or concerns, I will contact you. Again, thank you for all that you have done.