MIRRORING MATH LESSONS TO THE CLOUD: AN ONLINE TECHNOLOGY INTERVENTION CASE STUDY

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Abstract

The purpose of this research is to investigate the phenomenon of online technology enhanced mathematics education. This is a mixed methods technology intervention action research case study on investigating the impact on secondary geometry and calculus students' academic achievement and affect when their face-to-face lessons are mirrored to the Cloud as lesson videos and note files for students to access outside of the classroom. The investigator discovered educational benefits from this intervention based on the results of a quantitative analysis of the students' assessment scores and a qualitative analysis of interview, questionnaire, and observational data collected during the intervention. This work is the result of an inquiry by the school's stakeholders on how to use online technologies to enhance mathematics education.

Introduction and Literature Review

In this 21st century there is a need to increase the number of students who pursue college majors in STEM fields, for which a solid foundation in mathematics is needed (Gates & Mirkin, 2012). The far-reaching connectivity capabilities and instantaneous access to data and information through the Internet, as well as the advancements in educational hardware and software, all provide a plethora of technologies to enhance the teaching and learning of mathematics. This literature review provides a review of scholarly articles on recent research on integrating technology into mathematics education.

The effective integration of technology into the teaching and learning of mathematics has become an interest in the mathematics education community (Joubert, 2013). Studies indicate that students' achievement in mathematics courses generally improve with technology-enhanced teaching and learning (U.S. Department of Education, 2008). Our high technological information-rich world has created the need for a shift in learning models from a teacher-centered model to a learning community model in which each member is skilled in the use of technology and information access (Rodriguez & Berryman, 2002). The primary task of educators has moved beyond simply teaching students; now educators help students learn how to organize and utilize technology and information effectively (Rodriguez & Berryman, 2002). This paradigm shift requires that 21st century educators be proficient in navigating the Internet and utilizing appropriate technologies (Brown, 2005).

Although curriculum should not be designed around specific technology, research does support the utilization of multiple technology enhanced teaching formats including using technology for tutorials and practice problems (Bonham & Boylan, 2012). In 21st century mathematics education there is a new focus on utilizing educational technology that enables students to learn at their own pace (Mills, 2010).

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Basham and Marino (2013) suggest that teachers should integrate technology into their lessons to facilitate differentiated instruction and to address students' varied learning levels.

A research study on using online videos to create a flipped classroom was conducted by Stephens (2014) at San Jose State University. In this model students watched the lecture videos prior to attending class. Stephens (2014) found that in this flipped classroom model students were able to spend their class time working collaboratively with other students. This model also enables the instructor with more class time to work with students. Julie Decesare (2014), an Assistant Professor and Head of Education and Research at Providence College, writes that 21st century students expect that videos will be a part of their learning environment particularly in the flipped classroom teaching model. The open access educational videos on learning mathematics provided by Khan Academy have created controversy among some educators despite the support they have receives from key figures in education (Schaffhauser, 2014). Schaffhauser (2014) writes that a primary concern with the Khan Academy videos is that the videos are simply lectures without the opportunity for students to ask the instructor questions. Schaffhauser (2014) describes work done by Caitlin Grubb at Creekside Middle School in Zeeland, MI., in which she creates her own set of learning videos for her students. Schaffhauser (2014) emphasizes that as the teacher Grubb is able to create videos specific to the lessons she is teaching and is able to spend classroom time working collaboratively with her students. The educational advantage of using lesson videos is described in the article *How Technology is Changing Math Class* (2013) as an enhancement to the learning environment that provides the instructors with the ability to better monitor students' reactions while they are watching an instructional video in the classroom. Many creative mathematics teachers are now integrating online mathematics videos into their courses (Quillen, 2011).

Joubert (2013) investigated the perspectives of mathematics teachers and educational researchers on the benefits, concerns, and issues of utilizing and integrating technology in mathematics education by examining the abstracts of 124 papers submitted by authors from 33 countries to the July 2011 International Conference for Technology in Mathematics Teaching (ICTMT). These stakeholders frame their works around the practical and theoretical uses of technology in teaching and learning mathematics. In her analysis, Joubert developed a picture of the predominant concepts and ideas presented at this conference. She wrote about three key challenges of technology enhanced Learning (TEL), "connecting learners", "orchestrating learning", and "contextualizing learning" (pp.346-347). The first deals with facilitating a collaborative learning environment using connections between the learner and a more knowledgeable other through the Internet and digital media (Joubert, 2013). The second challenge is how to orchestrate learning through the teachers' and students' use of technologies (Joubert, 2013). The third challenge is on innovatively contextualizing learning by constructing meaning through interacting with technology (Joubert, 2013). Joubert found that these stakeholders primarily agreed that the use of technology for teaching and learning enhances the learning environment. Joubert's study indicates that there is as much interest in trying new technologies to facilitate the teaching and learning of mathematics as there are in continuing teaching and learning without trying new technology. More research that supports the use of technology in the classroom may encourage more mathematics educators to support a technology enhanced learning environment.

Background Summary

While the dedication and enthusiasm of instructors has a strong influence on students' learning (Abbasi & Iqbal, 2009; Schreyer-Bennethum & Albright. 2011), the integration of technology into mathematics teaching and learning enhances students' mathematical interests and understanding (Joubert, 2013; Schreyer-Bennethum & Albright, 2011). An increase in academic achievement from students' use of instructor created videos that supplement mathematics courses was identified by the Cleveland State Math Redesign lead member, John Squires (Mills, 2010). Attitudes of teachers influence the degree to which technology is integrated into the teaching and learning of mathematics (Joubert, 2013; Pierce & Ball, 2009). Independent of the teaching experience, teachers' negative perspectives on technology have transformed over time to positive ones as teachers recognize the beneficial impact technology has on learning (Pierce & Ball, 2009). The following online technology enhanced action research intervention study has been done in an effort to further inform mathematics educators on the potential benefits of integrating online technologies into mathematics education.

Research Purpose and Questions

The purpose of this research is to investigate the impact of using online technologies to enhance learning in a secondary mathematics classroom. What implications will come from these findings? How might this change the way that mathematics is taught? The specific question of inquiry in this research is this: What is the impact on secondary AP Calculus and Honor Geometry students' emotions, attitudes, beliefs, and academic achievement when the presentation of their class lessons, discussion notes, and homework assignments are mirrored to the Internet for students to access later? This report describes a technology intervention action research study. The results from this action research help to answer this question and add to the body of research in this area.

Hypothesis Statement

Recent research indicates that there are benefits from integrating technology into mathematics education (Joubert, 2013; Awang & Zakaria, 2012). Based on my classroom experiences, observations, and the articles I have read, I hypothesize that supplementing a mathematics education environment with digital technology that mirrors class lessons, notes, and homework assignments to the Internet for students to access will improve students' overall attitudes and increase students' academic achievement. This research supports this hypothesis through a comparison of assessment scores between the experimental and control groups, and an analysis of qualitative data collected from the groups that participated in the technology enhanced learning intervention.

Methodology

Participants

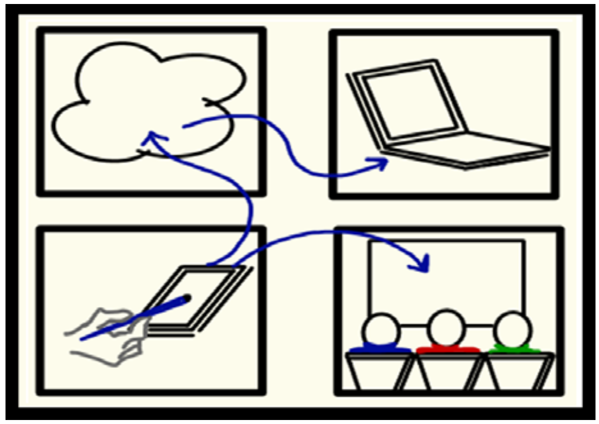
The participants in this study were not recruited. They were selected for this study based on their assignment to specific mathematics courses. The participants in this research are 71 tenth and eleventh grade students ranging in age from 15 to 19 years old from five secondary mathematics classes, two AP Calculus AB classes and three Honors Geometry classes. Twenty-five students were in the two secondary senior level AP Calculus AB classes and 46 students were in the three secondary junior level Honors Geometry classes. These 71 students attended Bishop Brady High School, a private, Catholic co-educational secondary school offering a college preparatory program in Concord, New Hampshire. This sample of 71 students typifies the Bishop Brady High School student body with respect to the students' demographics. The majority of the students come from over 68 cities and towns in New Hampshire. There is some diversity in their population through the school's international program, which brings in students from countries in South America, Asia, and Europe.

Materials

The material used in this research study included a set of AP Calculus student textbooks (Calculus: Graphical, Numerical, Algebraic, 3rd edition, by Finney, Deana, Waits and Kennedy), one corresponding teacher's edition textbook, three College Board AP Calculus AB unit assessments, a set of Honors Geometry student textbooks (Elementary Geometry, 3rd edition, by R. David Gustafson and Peter D. Frisk), one corresponding teacher's edition textbook, three unit assessments from the Elementary Geometry instructor resource book, a set of open-ended survey questions, a set of Likert survey questions, a set of student TI-83 calculators, a TI-83 calculator with an overhead projector and connection cable, a projector, an iPad, a MacBook Air, Quicktime software for video recordings and student interview recordings, the Goodnotes software application, the AirPlay mirroring software, the Gradebook grade recording software, and Microsoft Excel. The teacher, who is also the investigator, taught all of the courses in this study. This teacher is a College Board certified AP Calculus AB and AP Calculus BC teacher with 5 years of experience teaching AP Calculus AB, 8 years of experience teaching Honors Geometry, and 15 years of experience teaching mathematics.

The unobtrusive measure of a set of achievement assessments for each unit taught were used as part of a criterion reference instrument. These assessments covered the material in each unit and provided an adequate sampling of the material taught. The language on each assessment was clear and provided adequate sampling of types of problems taught as well as plenty of space for students' work. The AP Calculus achievement assessments reliably produced consistent results since they consisted of questions from previous College Board AP Calculus AB exams. The Honors Geometry achievement assessments reliably produced consistent results since they consisted of questions from the resource book that accompanies the students' textbook. The independent variable was whether or not digital communication technology enhancements were available to the class. The specific technology enhancement was the mirroring of all in class lessons, notes, practice problems, and homework review problems to the Internet as static PDF files and lesson videos for students to access later. To avoid the threat of confounding cause by students in the control group obtaining access to the mirrored course material, the control group was taught one year earlier in the fall of 2012 before the lessons notes and videos were made available in the Cloud. The achievement assessment questions required mathematical answers as specified in the existing units that correspond to the textbook. Each achievement unit assessment was carefully examined to make certain that the vocabulary was appropriate for the two student populations of sophomore and senior secondary students. The specific mathematical vocabulary used in the achievement assessments was the same as the mathematical vocabulary presented by the teacher during the teaching portion of the research. The content related validity focused on the use of the achievement assessments as instruments to measure content knowledge. The criterion related validity focused on ensuring that little to no technology enhanced learning as described in this study occurred prior to the administration of the unit achievement assessments to the control groups. Copies of this research question, the hypothesis, the achievement assessments, and the teaching material were made available to the math department faculty for validity review and modifications to insure a high degree of validity.

Procedure



The setting for this action research study was a mathematics classroom in the new wing of Bishop Brady High School. There was one participating teacher teaching each of the classes. Both quantitative and qualitative data were collected and analyzed. The participants in this research include 71 students in five secondary school level mathematics classes, two AP Calculus AB classes and three Honors Geometry classes. Twenty-five students from two senior level AP Calculus AB face-to-face classes were taught units from their AP Calculus curriculum. Both face-to-face classes were taught at the same school, using the same learning units and unit assessments. The experimental group of 11 students was taught with technology that mirrors all in class lessons, notes, and practice problems to the Internet for students to access later. This mirroring included static screen captures of class notes and videos of each lesson. The control group of 14 students did not utilize this technology enhancement. Forty-six students from three sophomore level Honors Geometry face-to-face classes were taught units from their Honors Geometry curriculum. These three classes were taught at the same school, using the same Learning units and unit assessments. The experimental group included 31 students from two Honors Geometry classes. These classes were enhanced with technology that mirrored all in class lessons, notes, and practice problems to the Internet for students to access later. This mirroring included static screen captures of class notes and videos of each lesson. The control group was one Honors Geometry class of 15 students. This control group did not utilize this technology enhancement.

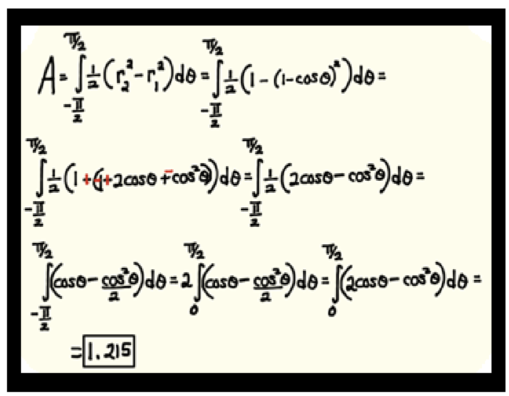
A quantitative inquiry was used to compare the academic achievement of the students in the experimental and the control groups through a comparative analysis of their assessment scores. This enabled the researcher to investigate the impact of this technology enhanced learning on the students' academic achievements. Since the students in these courses were selected based on their course schedules rather than randomly, the students were matched between the experimental and control groups into pairs based on their mathematics SAT and PSAT scores. Due to the small sample size that occurred after the SAT matching of the AP Calculus AB students, these students were also given a pre-assessment assessment prior to the technology intervention to compare their prior pre-calculus content knowledge. This pre-assessment presented more comparison data for the AP Calculus AB students.

A qualitative inquiry was used to investigate the influence this digital technology has on students' emotions, attitudes, and beliefs. Students' affect is best described using qualitative description; therefore, a qualitative naturalistic inquiry was used. This provided the investigator with the flexibility to explore patterns in students' emotions, attitudes, and beliefs as they emerged, enabling the investigator to make any necessary modifications to elucidate the study and to re-inquire based on these new findings as theories about the phenomenon developed (Patton, 2002). Observations and student interviews were implemented and recorded throughout the investigation. A holistic perspective sensitive to the students in this study developed through inductive analysis and synthesis. At the end of the intervention each student completed an anonymous questionnaire that included a Likert survey and open-ended questions.

The qualitative data collected included field notes from descriptive classroom observations, open-ended interviews with students, and anonymous questionnaires. The data sampling was done purposefully in an effort to understand students' emotions, attitudes, and beliefs and to recognize the dynamics in the classroom during the process of teaching and learning mathematics with the use of these digital communication technologies. Work was done in an effort to avoid bias and remain objective yet sympathetic to the needs of the students in the study.

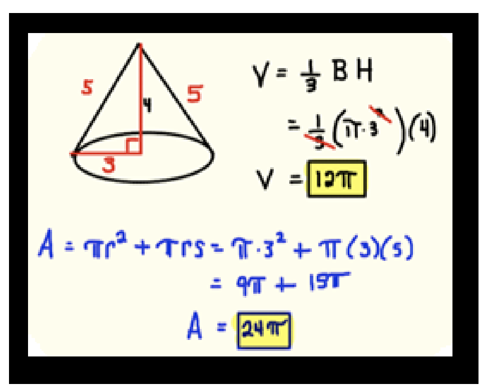
Methodological triangulation was achieved through the recorded quantitative achievement assessment scores and the three kinds of qualitative data: anonymous questionnaires, detailed classroom observations, and open-ended interviews.

The timeframe for this action research intervention was approximately three months running from October through December. The strategy that guided this qualitative action research was the regular review and assessment of the qualitative data. This study was performed in a relaxed non-threatening environment. Students were interviewed separately so that they were free to express themselves. Students were randomly selected for interviews throughout the investigation. In total seven students from the intervention groups were interviewed. Three were from the calculus group and four were from the geometry group. These interviews were recorded and saved. During the data collection process, students' identities remained anonymous through the use of coding. All data collected was stored as audio recordings, hardcopy surveys, and electronic field notes. This information was transcribed into a Word document. It was then categorized, sorted, and analyzed. This process was done mindfully in a way that was compassionate and fair to all students involved in this research. An effort was made to interpret the data correctly and clearly to maintain validity and relevancy. The observation and interview data was analyzed regularly to watch for trends and patterns in students' affect with respect to the digital technology used in the classroom.

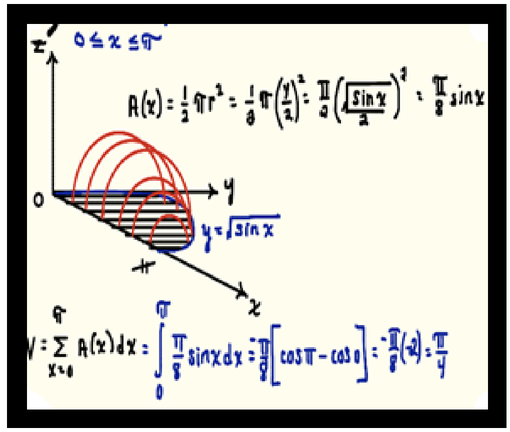


Descriptive statistics were used to analyze the assessment scores. Inferential statistics were used to reach conclusions based on the descriptive statistics to make judgments of the probability that an observed difference in assessment scores between the experimental and control groups was statistically significant. One of the goals was to compare the students' overall performance between the experimental and control groups to check for a possible significant improvement in the students' overall performance which would support the hypothesis that including educational instruction with the technology enhancements used in this study as it applies to each lesson when teaching secondary mathematics will improve the overall performance of the students in these courses.

Observations and Intervention Modifications



The quantitative data consists of three summative assessments administered to both the AP Calculus AB and the Honors Geometry groups. The three AP Calculus AB assessment topics were pre-calculus, limits and continuity, and the derivative. The three Honors Geometry assessment topics were an introduction to Euclidean geometry and reasoning, proofs involving triangles, and indirect proofs involving parallel lines and polygons. During the action research the researcher regularly reflected on the ongoing qualitative data that was collected. This process of continuous listening, watching, and reflecting was instrumental in discovering issues and solutions and allowed the researcher to work towards improving the use of digital communication technologies in this technology enhanced education intervention. The researcher observed that students came to class energetic and excited about this new technology. Students who struggled to follow along in the past were now eager to participate in class problem solving discussions. Several students brought in their own iPads on which they installed the same Goodnotes software application that the teacher was using. Students copied the Dropbox notes file onto their iPads and added their own notes during class.



Early in the intervention technical difficulties occurred. Each issue was resolved quickly. Network discontinuity disrupted teaching. When the small Catholic school experienced problems with their intranet the AirPlay failed. A successful solution was implemented. I created an internal closed classroom network with an access point. Several students described difficulties accessing videos from Bishop Brady's course management system, Edline. For easier access and to allow for the storage of longer lesson videos, I moved the lesson videos to a YouTube channel. Overall students were pleased with this move. As the course notes in the dropbox grew the size of the dropbox was increased. As the dropbox notes files grew they also became difficult for the students to download and read. For this reason I reorganized these files into separate lesson module files so that students would not need to page through large PDF files in an effort to locate the content being studied.

Through the use of classroom observations it became evident that students who previously struggled with note taking appeared to follow course lectures better and to participate more frequently. Students who were sometimes chatty were now quiet during the video recording of new lessons. When lessons were recorded most students quietly followed along well with little distraction. As students became comfortable with the recording of lessons they began asking constructive questions during the recording. Student athletes who had struggled in their math courses during the previous year were pleased that they would not miss class lessons when they left school for competitions. Instead these students would watch the online lesson video, review the class notes, complete their homework assignment, and return to class well prepared. Overall the classroom observations indicated that the students were enthusiastic about the use of this technology in the classroom.

Results

Quantitative Analysis

In January, after completing the intervention implementation and data collection process the data were analyzed. The results from the three summative assessment given to the two AP Calculus AB groups after the students were matched into pairs based on their SAT scores are displayed in Table 1 below.

Table 1. Calculus student assessment scores. Unit 1 assessment was given prior to the intervention. The sample size was reduced to 8 after matching students into pairs based on their SAT scores.

	Control Group			Intervention Group		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
1	65	55	60	67	60	80
2	75	69	66	76	81	64
3	90	77	84	76	81	73
4	77	76	70	60	68	82
5	80	51	72	71	60	87
6	83	92	80	94	94	93
7	94	91	98	79	98	90
8	91	87	80	93	88	94
mean	81.88	74.75	76.25	77.00	78.75	82.88
standard deviation	9.69	15.61	11.88	11.81	14.72	10.40

The first assessment was given to the control group and the experimental group prior to the commencement of the technology enhanced learning intervention. It was based on pre-calculus concepts that were taught to these students during the previous year. The results of this assessment show that the mean for the control group is higher that the experimental group. The second and third summative assessments were given to the control group and the experimental group after the intervention was in process. The analysis of the assessment scores for these assessments shows that the experimental group performed better on the two post-intervention assessments. Figure 1 displays box plots that compare the spread and center of the results from the three summative assessments given to the AP Calculus AB groups after the students are match based on their SAT scores.

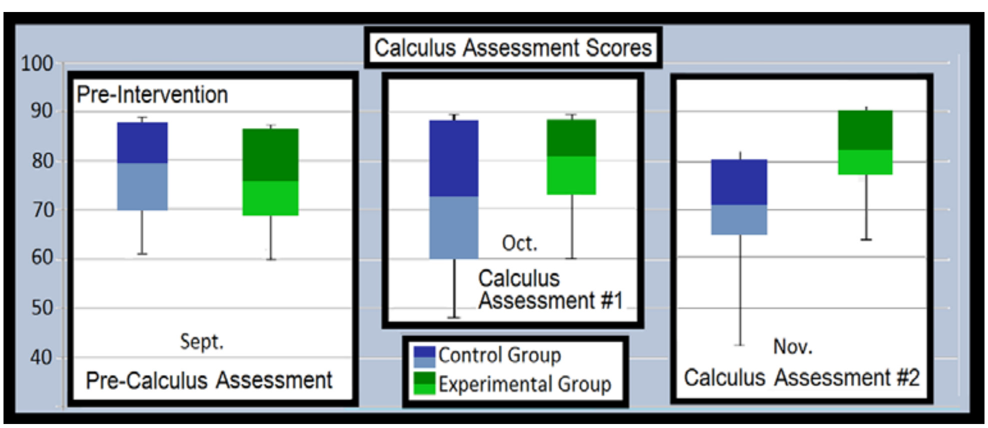


Fig. 1. Calculus student assessment scores. Unit 1 assessment was given prior to the intervention. The sample size was reduced to 8 after matching students into pairs based on their SAT scores.

The first two box plots on the far left represent the summative assessment results for the control group and the experimental group prior to the intervention. In these two box plots the control group assessment scores on the left are slightly higher with a higher measure of center than the scores from the experimental group on the right. Overall the first assessment scores for the two groups are similar. In figure 1 the middle two box plots represents the summative assessments scores of the control group on the left and the experimental group on the right after the intervention began. In these box plots the measure of center for the experimental group's scores are higher and the spread of these scores for the control group is smaller. This indicates that the technology enhanced learning intervention may be influencing the learning of limits and continuity for the students in the intervention group. In the third summative assessment the measure of center for the experimental group on the right is greater than the measure of center for the control group on the left. This difference in measures of center appears to be more noteworthy than in the second summative assessment. The students in the experimental group have now had experience with using the online class notes and videos prior to the third assessment. The box plots for the third assessment support the theory that the students in the experimental group may have learned how to utilize the newly available technologies and they may understand the concepts in the derivative module better than the students in the control group due to the use of this technology.

The results from the three summative assessment given to the two Honors Geometry groups after the students were matched based on their PSAT scores are displayed in Table 2 below.

Table 2. Geometry student assessment scores. The sample size was reduced to 14 after matching students into pairs based on their PSAT scores.

	Control Group			Intervention Group		
	Unit 1	Unit 2	Unit 3	Unit 1	Unit 2	Unit 3
1	66	66	66	86	93	80
2	92	95	100	94	93	92
3	82	82	77	88	82	87
4	66	83	71	84	85	80
5	76	72	73	98	93	92
6	87	86	100	100	89	89
7	92	84	67	94	82	76
8	76	63	73	98	89	86
9	74	76	50	92	89	83
10	84	86	37	88	82	74
11	97	77	65	98	94	99
12	92	97	85	91	89	85
13	74	74	63	79	81	85
14	79	77	75	96	89	96
mean	81.2	79.9	71.6	91.9	87.9	86.0
standard deviation	9.9	9.7	16.8	6.2	4.7	7.2

All All three summative assessments were given to the experimental geometry group after the intervention was in process. The analysis of the assessment scores for these three assessments shows that the experimental group performed better on the three assessments.

Figure 2 contains box plots that compare the results from the three summative assessments given to the two Honors Geometry Geometry groups after the students were matched based on their PSAT scores.

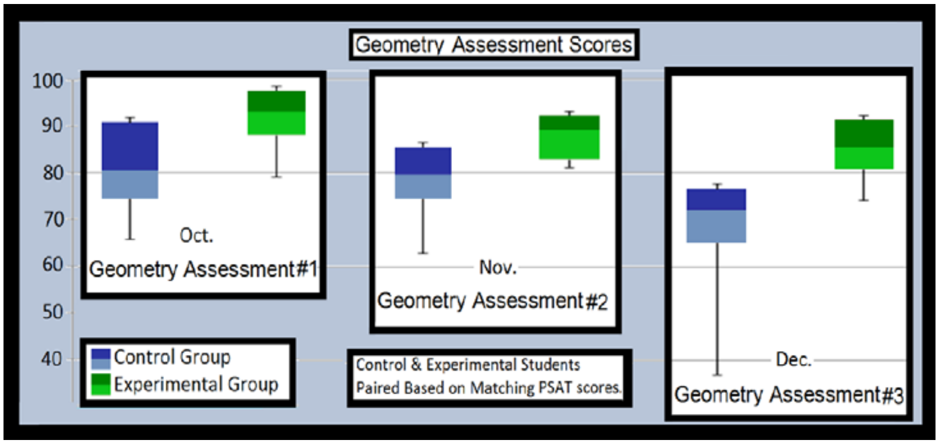


Fig. 2. Geometry student assessment scores. The sample size was reduced to 14 after matching students into pairs based on their PSAT scores.

These box plots provide a visual for comparing the spread and center of the results from the three summative assessments given to the Honors Geometry groups. The first two box plots on the far left represent the summative assessment results for the control group and the experimental group after the intervention began. Here we can see that the experimental group's assessment scores on the right are higher with a higher measure of center and a smaller spread than the scores from the control group on the left. The middle two box plots represent the second summative assessment scores for the control group on the left and the experimental group on the right. Here the measure of center for these scores is higher and the spread of these scores is smaller for the experimental group. The last two box plots on the right represent the results from the third summative assessment. Here again the measure of center for the experimental group on the right is greater than the measure of center for the control group on the left. This difference in measures of center appears to be more substantial than in the first and second summative assessments. The students in the experimental group have now had weeks of experience with using the online class notes and videos prior to the third assessment. The box plots for the third assessment support the concept that the students in the experimental group may be learning how to use the newly available technology and are understanding the concepts in the third geometry learning module better than the students in the control group due to the use of this technology. Here the assessments scores of the control group have a downward trend as the coursework of solving proofs is becoming more rigorous. This has been an unfortunate trend in the history of this honors geometry course. As the proofs become more difficult to solve, some students move to a non-proof based geometry class at the end of the first quarter, which is after the third assessment. This was not the case in the experimental group. In this group the assessment scores remained at a similar level and no students are failing.

A one-tailed t-test with a 95% confidence interval was used to check for a statistically significant difference between the mean assessment scores in the control and the intervention groups. The research hypothesis is that the mean score for a control group is less than the mean score for the corresponding intervention group. The null hypothesis is that the mean score for the control group is equal to the mean score for the corresponding intervention group. When comparing the AP Calculus AB assessment that were given after the intervention began the difference in mean assessments scores was determined to not be statistically significant. This may be because the technology was not yet facilitating learning. It may also be due to the fact that the control group consisted of strong students which is evident from the first pre-intervention assessment. It is also possible that the students in the experimental group were experiencing a learning curve with the new technology. This was not the case for all three of the geometry assessments. The results of the t-test are displayed in Table 3. Here the null hypothesis is rejected and the alternative hypothesis is supported. (The null hypothesis is that the means for the two groups are equal and the alternative hypothesis is that the means for the control group is less than the means for the intervention group). Therefore the increase in mean assessment scores for the geometry students in the intervention group is statistically significant.

Table 3. T-test for statistical significance between the mean scores of the control and the intervention groups' geometry assessment scores after matching into pairs based on PSAT scores.

Geometry Group	Test	N	Mean	Standard Deviation	SE Mean	T-Value	DF	P-Value
Control	1	14	81.214	9.870	2.638	-3.42	21	0.0013
Intervention	1	14	91.857	6.188	1.654			
Control	2	14	79.857	9.742	2.604	-2.77	18	0.0063
Intervention	2	14	87.857	4.655	1.244			
Control	3	14	71.571	16.805	4.491	-2.95	17	0.0045
Intervention	3	14	86.000	7.222	1.930			

Table 4. Intervention students' anonymous Likert survey.

	Strongly Agree	Agree	Somewhat Agree	Disagree
Course resources contribute to my understanding of the subject.	25	15		
Use of technology is helpful.	26	25		
Edline posts are easily understood and helpful.	14	23	3	1

The anonymous student responses to the Likert scale survey questions (see Table 4) reveal that students agreed that the course resources contributed to their understanding of the subject. Students also agreed that the use of technology was helpful. Only one student disagreed that the school's learning management system, Edline, included postings that were easily understood and helpful for assignments and class information.

Qualitative Analysis

A qualitative analysis of the open-ended questions in the anonymous student surveys reveals that the majority of the students were pleased with the use of technology in the classroom. When describing their thoughts they used the words *like*, *helps*, *accessible*, *helpful*, *benefit*, *clarify*, and *confident*. These students described different ways in which the technology benefited their learning. One student wrote that the use of the iPad with a projector "helps to clarify concepts." Several students explained that the use of technology helped them to "feel confident going into the test." Only one student wrote a negative comment about the use of technology with the statement "I wish sometimes she would just use the board when going over homework". When evaluating students' perspectives on the class lesson and homework review notes that were available on the Internet, it became evident that students were pleased with this technology. They wrote positive comments about the online course notes. They used these words to describe the online course notes: *like*, *love, available*, *assessable*, *helpful*, *helps*, *understand*, *refresher*, *lookup*, and *examples*. One student explained that it helped to make everyone's life easier because all of the notes from class were available online. This student suggested that more instructors should use this technology. Several students explained that the online class notes were helpful when they were absent from class due to sports or illness. Although many students described the notes as organized, one student expressed that "sometimes the order and labeling of notes is confusing." Other students explained that the online course notes help them to understand the material more easily, especially at night when they are able to look at examples in the course notes. A qualitative analysis of students' perspectives of the online lesson videos revealed that students were also pleased with these videos. Students wrote that they appreciated the lesson videos that were available to them online. They used these words to describe the lesson videos: *like*, *love*, *handy*, *accessible* and *helpful*. Some students explained that they did not fall behind on learning material when they missed classes because they would watch the lesson videos at home. They also described situations in which they would refresh their memory of class lessons by watching the lesson videos at night. One student explained that when watching the lesson videos he found things that he missed during class. Several students explained that the ability to pause and rewind the lesson videos helped them to understand the lessons better. They also found that the videos were helpful during their test preparation time. One student wrote "I am someone who understands in class but sometimes gets lost in the homework, so I like being able to look back at the videos." Only one student explained that she did not use the videos because she did fine without them.

The open ended interviews revealed that while many students liked both the online class notes and the lesson videos, many students viewed the online class notes more frequently than the lesson videos. From these interviews it became apparent that students who learn well in a traditional classroom tended to not watch the online lessons videos and those who need additional help after class watched the videos regularly.

Conclusion and Discussion

This action research study indicates that the technology enhancement of mirroring mathematics class lessons, discussion notes, and assignments to the Cloud for students to access later facilitates students' positive emotions, attitudes, and beliefs, and creates an effective learning environment with increased academic acheivement. The qualitative data indicates that students who struggled in the past performed better in the intervention groups; and that top performing students felt that they would generally perform well with or without the technology intervention. Geometry is a required course for all students in the school and calculus is limited to students who excel in mathematics. For this reason the sophomore geometry students were more representative of the student population than the calculus student because the calculus students represent the top performing mathematics students in the school. The lowest performing students in the intervention group outperformed their peers in the control group in all the geometry assessments and in the third calculus assessment. While some students in the control groups failed their assessment when the work became challenging, no students in the technology intervention group failed an assessment. The qualitative assessments reveal that students feel confident and well prepared when this technology is part of their learning environment. Students who struggled in the past due to missing class for sporting events or illness and students who have difficulty with balancing note taking and listening benefit from this technology.

Overall there were higher assessment scores for students in the technology intervention groups than there were for the students in the control groups. There was a statistically significant difference in the mean assessment scores between the Honors Geometry intervention and control groups for all assessments given during the intervention study. There is also a notable decrease in the spread of assessment scores for the students taught with this technology.

This mixed method analysis suggests that the support from this technology intervention may provide the necessary scaffolding to help struggling students by allowing them to review and relearn course material online. This research demonstrates the benefits of mirroring mathematics lessons to the Cloud. While more research should be done in this area, the technology for this exists now and educators should consider integrating this technology into their teaching. ■

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