Virtual graphing calculator applied in learning and the performance based on teaching experiment method

Peijie Jiang*
School of Mathematics and Statistics, Hunan Normal University, Changsha, Hunan, China

ABSTRACT

Virtual technology applications in learning are increasing due to ICT's fast development. But how to apply virtual technology to education is the problem we are facing. This paper proposes a quasi-experimental study. Participants in this study were students in two parallel classes in the first year. The teacher used a virtual graphing calculator to provide students with learning in the experimental class. In the control class, the teacher did not use virtual technology. Students in both categories were tested after class and two months later. The results show that the learning effect of using virtual technology is slightly better, but it is not significantly different from the learning of the control class. In addition, there is no sustained effect in learning with a virtual graphing calculator. Instructors cannot give up traditional problem-solving training for students. Learning with virtual technology should pay attention to absorbing the advantages of conventional learning.

Keywords: Virtual technology, virtual graphing calculator, mathematics teaching

1. INTRODUCTION

With the development of information and communication technology (ICT), virtual technology to assist in teaching has become increasingly necessary. Compared with the traditional teaching methods, more and more people are using various information communication technologies to improve the quality of education[1]. Moreover, The COVID-19 pandemic has made e-learning increasingly important[2, 3]. It has boosted the use of digital technologies in education[4].

A study designed to determine secondary school mathematics teachers' perceptions and attitudes toward using technology in mathematics education found that teachers' attitudes toward technology were positive[5]. The current focus of related research has shifted to how teachers use different technologies to facilitate teaching[6].

Some people have applied dynamic geometry software, virtual reality technology, and computer algebra systems to mathematics teaching. Students' involvement in creating the on-screen actions enables them to connect unfamiliar mathematical objects, and their paradigmatic relationships and properties[7].

Dynamic mathematics software has many features, such as flexible and convenient operation, powerful mathematics teaching functions, and dynamic resource series. It can handle mathematical knowledge of geometry, algebra, and probability[8]. The very nature of dynamic mathematical representations—being intrinsically temporal, occurring over time—offers different opportunities for narrative thinking than the static diagrams and pictures traditionally available to learners[9].

Functions are the main thread of middle school mathematics content and run through all mathematics courses. Through the study of functions, students can understand the concept of functions, master their properties, develop abstract thinking skills, and use related mathematics knowledge to solve practical problems[10]. But the idea of function is abstract. Using computer algebra systems (CAS) such as graphing calculators (GC) can help students understand functions more efficiently and help them learn.

The first type of handheld technology mentioned as a part of the secondary school curriculum in 1986 was a Casio fx-7000G model. The newest development of this type of technology combines various learning environments like CAS and dynamic geometry computer software, such as dynamic geometry Sketchpad, Cabri, or GeoGebra[11-13].

A mixed-methods study[14] investigated the effect of a graphing calculator intervention on grade 11 students' performance in solving quadratic inequality problems. The quantitative aspects of the study involved an experimental group and a

* peijiejiang@hunnu.enu.cn

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control group design, where the experimental group received instruction using GC activities and the control group did not use GC for teaching. The results confirmed that the quadratic inequality problem-solving performance of the experimental group was statistically significantly improved.

Another study[15] aimed to investigate the effect of problem-solving instruction supported by graphing calculator programs on mathematics achievement and attitudes in the subject of transformation geometry. Participants in this study were 49 seventh-grade students in a middle school, using a pre-test, post-test quasi-experimental design with two groups. The results showed a significant difference in mathematics achievement in the experimental group, while there was no significant difference in geometric attitude between the experimental and control groups.

Many researchers have also researched the application of graphing calculators to teaching[16-19]. However, these studies used a physical handheld graphing calculator, and there are few studies on applying a virtual graphing calculator to teach. The Virtual Graphing Calculator is an integrated virtual technology that combines multiple environments and functions. Virtual graphing calculators do not require physical support and are convenient for learning. It is easier to use, more affordable, and more versatile, especially under the panic of the new crown pneumonia epidemic. Therefore, it is indispensable to study teaching with the application of a virtual graphing calculator.

Determining whether educational technology is effective through high-quality experiments is perhaps the most critical requirement of educational reform[20]. It is necessary to carry out an empirical study on the application of virtual graphing calculators to teaching. In this consideration, this paper has sought to answer the following questions through a learning experiment:

(1) Is teaching more effective with a virtual graphing calculator in learning?

(2) What are the considerations for learning with a virtual graphing calculator or other technologies?

2. METHODOLOGY

2.1 Participants

Participants were students from two parallel first-year high school classes. The experimental and control classes are two similar classes divided by previous test scores. The student's cognitive level in the two types is roughly the same, and the teacher of both styles is the same person. The teacher usually prepares lessons in the same way and teaches in the same way. There were 52 people in the experimental class and 51 in the control class. The teacher used a virtual graphing calculator in the experimental group but not in the control group.

2.2 Technology

A virtual graphing calculator is computer software that simulates a physical handheld graphing calculator. It can realize all functions of a graphing calculator (except the acquisition function of sensor data such as light, electricity, and heat) such as numerical calculation, drawing, dynamic graphics, and simple symbolic calculation. Whether teaching in the classroom or at a distance, the virtual graphing calculator can be used by teachers to demonstrate during teaching. It is instrumental in learning. Figure 1 is the interface of the virtual graphing calculator used in this study.

2.3 Measurement question

The purpose of the measurement question is to test the effectiveness of learning. The method is to assign points to the students' answers and make judgments according to the results of the assignments. According to the teaching content, after consulting three senior mathematics teaching experts, the measurement question is designed as follows:

The monotonicity of the function $f(x) = x + k/x \, (k > 0)$ is judged and discussed with its maximum and minimum values.

The monotonicity of a function qualitatively describes the relationship between the function value and the independent variable in a specified interval. It can accurately describe the rising and falling trend of the function graph. The function above is called a double hook function and has many nice properties.

The measurement question aims to directly test students' understanding of the monotonicity of the double hook function. Because the measurement question involves two knowledge points, the monotonicity, and the extremum value, the measurement question is 2 points. Students get 1 point for correct monotonicity (0.5 points for monotonicity in only one interval) and 1 point for proper discussion of maximum and minimum values (0.5 points for only one value).

Figure 1. The interface of a virtual graphing calculator.

2.4 Procedure

The experimental design type is a two-group time-lapse experimental design. The researcher found that almost all students had never heard of the double-hook functions. Considering that the content of this function does not appear as the main text in their textbook and the measurement question is complex, the researcher did not conduct a pre-test before the learning. This study assumes that students cannot complete the measurement question before class. At the end of the teaching, one measurement (the first post-test) is conducted to determine whether the learning has an immediate effect. After two months of teaching, the students will be measured again (the second post-test) to determine whether there is a sustained effect on their learning. According to the results of the two measurements, the researcher comprehensively analyzes the impact of learning with virtual technology.

2.5 Data analysis

After the students complete the measurement question, the researcher hires two expert teachers to evaluate and score the answers. If the scores given by the two talented teachers are consistent, the average of the scores of the two expert teachers will be taken as the final result. Otherwise, it will be re-graded until their grading results are consistent. After collecting the data, the researcher uses SPSS 20 to process them.

3. RESEARCH RESULT

3.1 Descriptive statistics

The data obtained from the measurement at the end of the learning (the first post-test) are 52 answer sheets from the experimental class and 51 from the control class. Table 1 shows the scores of the students' answers.

In Table 2, A, B, C, D, and E represent the number of people who scored 0, 0.5, 1, 1.5, and 2 points. Not difficult to see, learning with a virtual graphing calculator can better help some students understand mathematical concepts.

Table 1. The scores of students.

Answers (points)	Experimental class	Control class
Only answered the monotonicity on the right side (0.5)	3	0
Only answered the monotonicity on the left side (0.5)	0	2
Only answered the monotonicity correctly (1)	10	10
Only the maximum and minimum values are correct (1)	9	4
All correct (2)	13	9

Table 2. The score grouping of students.

Group	A	B	C	D	E
Experimental class	17	3	19	0	13
Control class	26	2	14	0	9

3.2 Comparison of experimental class and control class

Table 3 shows the mean and standard deviation of the experimental and control group scores. It is not difficult to find from the data that the results of the experimental class are slightly better, but the degree of dispersion of the two scores is almost the same.

Table 3. Comparison of mean and standard deviation.

Group	N	Mean	Std.
Experimental class	52	.8942	.76911
Control class	51	.6471	.76351

An independent sample t-test was performed on the scores of the two types, and Table 4 shows the results.

There is no significant difference between the experimental and control classes' scores $(t = 1.637, p = 0.105 > 0.05)$. Learning the double hook function with a virtual graphing calculator is not significantly better than learning without virtual technology.

Table 4. The t-test for equality of means (*p < 0.05).

t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
1.637	101	.105	.24717	.15103	-.05243	.54677

3.3 Sustained effect of the teaching with virtual technology

Two months later, the researcher organized the students in the experimental class to complete the same measurement question again. The researcher collected a total of 52 valid answers. Three students got 2 points for complete, correct answers; 2 students only got 1 point for solutions of correct monotonicity; others got 0 points for all wrong answers or no answers. The paired sample t-test results of the two post-tests of the experimental class scores are shown in Table 5.

There is a very significant difference in the scores of the two post-tests in the experimental class $(t = 7.588, p = 0.000 < 0.01)$, and the effect size are large $(r = 7.3)$. Using a virtual graphing calculator assisted in learning the double hook function has no sustained effect. Students almost completely forget what they have learned in 2 months.

Table 5. Paired samples test (*p < 0.05, ** p < 0.01).

Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
			Lower	Upper			
.74038	.70357	.09757	.54451	.93626	7.588	51	.000

4. DISCUSSION AND CONCLUSION

This study uses a teaching experiment method to test the effect of virtual graphing calculators in mathematics teaching. The conclusion is that virtual technology to support learning is effective, but the result is insignificant, and there is no sustained effect. The results indicate that the virtual graphing calculator is not as effective as imagined, and teachers should not be too optimistic when using virtual technology. Using virtual technology to assist in teaching is not necessarily effective and needs to be considered in advance.

The theoretical value of this study is to show that the application of virtual technology alone is not enough to improve teaching effectiveness. Teachers should not rely too much on information technology in their teaching practice. Even though the teacher uses powerful new virtual technology to help the instruction, students still need a certain amount of exercise to do it themselves.

As the famous mathematics educator Polya pointed out, students can only learn to solve problems by solving problems. Students need to improve their understanding and memory of concepts by doing exercises. Learning with virtual technology should pay enough attention to absorbing the advantages of traditional learning methods.

In addition, this study's limitation is that only one item is used to test students. Moreover, this test question is too difficult, which will cause inevitable frustration to the students participating in the research. Future studies should develop more accurate scales and conduct longer-term experiments and design studies.

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