GeoGebra integrated instruction: Effectiveness and empowerment

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Abstract

Integrating ICT in mathematics instruction has been becoming the pertinent issue in Nepal. In this context, this paper explores the effect of GeoGebra embedded instruction in students learning, particularly in geometry at school level. GeoGebra is the widely used open source software which can cover almost all areas of school mathematics. So, this paper will contribute the important research findings on whether the ICT integrated instruction plays effective roles in teaching and learning mathematics. Quasi experimental design was used to conduct the study. Two parallel sets of achievement test papers, observation note and interview schedule were used to collect the data from the respondents. The data obtained from test paper was analyzed using mean, standard deviation and t-test at 0.05 level of significance. Whereas the data obtained from interview and observation wasanalysed by using general inductive approach. The result of the study indicated that the achievement score of experimental group was significantly higher than control groups after using GeoGebra in teaching mathematics.Besides, the quantitative findings, students in experimental group seemed more active and motivated during the intervention. Creativity and self-exploration are two important skills they developed after the intervention. It can be concluded that ICT embedded instruction is an effective approach for better mathematics learning.

Keywords: GeoGebra, ICT, effectiveness, self-exploration, visualization

Introduction

Achievement in mathematics at Secondary Education Examination (SEE) has been creating immense issue in education system of Nepal. Some of the stakeholders have started discussion on relevancy of mathematics in school level curriculum and some of them argued to add practical portions in mathematics. Both of these arguments are not the solution. We cannot imagine the school level curriculum without mathematics. We have to rethink on our curriculum and its focus. Does it really have to be need-based? Are we teaching mathematics how it shouldbe taught? Are we evaluating students correctly? As my experiences being a mathematics teacher, we are only focusing onrote learning, our textbookis also focusing on remembering procedures rather than understanding the concepts of the content, our teaching method mostly exam oriented and we are prioritizing merit-based education system only. The knowledge obtained from rote learning is very impartial and incomplete. Making mathematics practical is very high sounding and lovely version. But to make mathematics practical we have to think practically. Our teaching learning activities should focus on practical and application aspects of mathematics. For this purpose, integration of information and communication technology (ICT) is essential. Findings of many national and international level researchers show that ICT integration is very effective for the betterment in the performance of mathematics (Dogan, 2010;Erhan& Andresen 2013;Herceg&Herceg, 2010;Kandel, 2017; Leong, 2013; Thanet, 2019).

ICT in Mathematics Education

The age of the 21st century is known as the age of information and technology. Every field of society cannot be detached from science and technology including education.

Lifestyle of every personis greatly affected from technology. We cannot spend a single day without technology. Effect of technology has also seen greatly in teaching and learning processes. Teachers and textbooks are not only the sources of knowledge. Students have access to the multiple sources of knowledge such as TV, digital media, cable network, the Internet and social media, etc. These tools can make crucial contribution in knowledge construction besides textbooks and teachers. In my observation, there is a gap between the progress of the society adapting technology and instructional activities we are practicing in the classroom. Teaching and learning processes is still in the same format to some extent. Teacher centric mode where teacher imparts knowledge to the student is still prevalent in the classroom. Still we are hesitating to disseminate the multiple sources of knowledge to students. Managing environment for technology integration and engaging skills (Bebell&O'Dwyer, 2010; Zucker& Light, 2009). Students in learning process with technology may be challenging for teachers but this is essential now. The general incorporation of technology into classrooms may not improve learning. Rather, what is important is how both teachers and students use technology for knowledge generation and teacher's roles are crucial to transform more resources into better learning opportunities. If they are not adequately competent and supported to make the best use of resources, they may feel lost.

ICT is not only providingaccess to knowledge anywhere at any time, but also assigning equal networking and communication opportunities that enable knowledge sharing, participation and lifelong learning. In realization of these huge possibilities of ICT in education, Government of Nepal has also accepted the potentiality and started to invest in the development of ICT infrastructures in education institutions. Alongside these investments, the role and capacity of teachers have become more critical than ever. The challenge is how to enable teachers not only to overcome the technology barriers but also to empower them to integrate appropriate technology into the teaching and learning process. It is sure that technology can be a powerful education multiplier, but we must know how to use it. Technology cannot workitself, it works with the intellect of human. It is not enough to install technology into classrooms,it must be integrated into learning (Driscoll, 2002).

GeoGebra and Mathematics Teaching

Nowadays, there are varieties of technological tools we can use in teaching and learning mathematics. Teachers can choose varieties of software to make mathematics teaching learning activities more effective and lively. Among different software, GeoGebra is one which was developed by Markus Hohenwarter in 2001/2002 as a part of his master's thesis at the University of Salzburg in Austria. It is free open-source dynamic software which offers geometry and algebra features in a fully connected software environment. GeoGebra is free and user-friendly software that connects geometry and algebra into one (White, 2012). The GeoGebra software can also be used as an enabler in teaching and learning of Mathematics, and more specifically of geometry. The use of the GeoGebra software not only increased student scores, but also enabled in the realization of vibrant classroom with cooperative and collaborative principles of learning (Shadaan& Kwan, 2013).

The use of GeoGebra in the recent years is expanding all over the world. In our context, Tribhuvan University has adopted ICT in mathematics course at Bachelor and Master's levels as well. In that course, GeoGebra covers major portion. In addition to that, many master's level students are doing research in the effectiveness of GeoGebra in learning mathematics. From this scenario GeoGebra software has been becoming a more popular and useful tool for Nepalese context as well. Most of the research studies in national as well as international contexts are done in measuring the effectiveness of ICT specially GeoGebra in the cognitive perspective only. But effectiveness does not refer to only cognitive aspect, it should be non-cognitive aspects of students learning such as creativity, participation, motivation, exploration and evaluation of self-learning. So, in this small scale research I have tried to explore the effectiveness of GeoGebra in students learning concerning the cognitive as well as non-cognitive aspects.

Theoretical Understanding

Teaching and learning activity in Nepal is still based on traditional mode where teachers are considered as an authentic and single medium of knowledge transfusion. The conventional practices of educating students include teachers choosing and enforcing the content and the students adopting it. The teacher is considered as the subject of the learning process, while the pupils are mere objects (Freire, 2000). In this banking concept of education, knowledge is a gift granted by those who consider themselves knowledgeable upon those whom they consider to know nothing(Freire, 2000). This view opposes the reality that the education must begin with the solution of the teacher-student contradiction. Teachers make learners to memorize definitions and answer of the text or exercise-questions. Maintaining note book of exercise is the teaching all about. Such type of education "anesthetizes and inhibits creative power" (Freire, 2000). Teaching-learning process cannot be completed with only this activity. Teaching must foster critical thinking and creates active and motivates learners, not the passive receiver. The concept of ICT in education emerged through the constructivist ideology for learning. Constructivism is a learning theory which suggests that individuals construct knowledge and meaning from their experiences (Orlando, 2013). As constructivist practices, ICT embed pedagogy is often used and refers to student-centered, where there is teacher-student and student-student collaboration and co-construction of knowledge (Hennessy, Deaney, Ruthven &Winterbottom, 2007; Killen, 2009).

As my experiences, ICT integration in learning is based on the learning by doing assumption. Those who can do mathematics using ICT can learn mathematics effectively. Integrating ICT like GeoGebra in mathematics required efficient knowledge not only of technology but also of mathematics. When we are starting to visualize the mathematical concept through technology then we simultaneously start to think mathematical concepts in very constructive way. To visualize any mathematical problem through GeoGebra we should break-down the problem into very fundamental pieces of concept. The idea which I have discussed is more or less based on APOS theory within the constructivist philosophy. APOS theory is the framework which is used to explain how individuals mentally construct their understanding of mathematical concepts (Arnon et al., 2014). The acronym APOS stands for action, process, objects and schema and this process is done in mental mechanisms of interiorization, coordination, reversal, encapsulation, and thematization (Aronon et al., 2014). APOS theory is principally a model for describing how mathematical concepts can be learned; it is a framework used to explain how individuals mentally construct their understandings of mathematical concepts. This theory enhances students higher order mathematical thinking ability (Mudrikah, 2016).

Activities, Classroom discussion and Exercise (ACE) process of teaching cycle which is based on APOS theory is considered as the framework for conducting the teaching learning activities during the experimentation.The ACE is a repeated circle of these three components. The activities, which form the first step of the cycle are designed to foster the students' development of the mental structure. In this activity, students work cooperatively in groups on tasks designed to help them to make the mental constructions suggested by the genetic decomposition (Weller, Arnon& Dubinsky, 2009). The second part of the cycle is classroom discussion in which students share their ideas in the classroom and this discussion give opportunity to reflect on their works. At last, the exercise helps to support in the continued development of the mental constructions.

Methods and Procedures

Pre-test, post-test non-equivalent quasi-experimental group design was adopted to accomplish the study. Since my studyfocused on to explore the effectiveness of the GeoGebra software in learning mathematics, I chose two secondary schools of Kathmandu district by using convenience sampling. At first, I conducted pre-test on grade x students of four secondary schools of Kathmandu district located in Kirtipur municipality. After obtaining the pre-test result, two schools whose pre-test result were not significantly different, with same locality and having same physical infrastructure were chosen. In selecting the schools, firstly, I consulted head teacher of four schools and observed the schools computer lab for the feasibility of using GeoGebra in teaching mathematics. After choosing two schools, I took one experimental and one control group by coin tossing method. Experimental group got intervention (treatment) that was GeoGebra integrated teaching and other group was taught using conventional method of teaching. GeoGebra embedded teaching method was considered as an independent and mathematics achievement of students was considered as dependent variables and other affecting variables such as content matter, teacher, time duration and assessment techniques were tried to control as far as possible.

I went through the three phases in the study that were pre-experimental phase, experimental phase and post-experimental phase. In pre-experimental phase, at first I prepared the GeoGebra embedded teaching module and achievement test paper for pre-test and post-test. After that I chose my research site and determined the experimental and control group through the use of pre-test score and other contributing variables in selected schools. In the experimental phase, I myself taught parallelogram and circle to both groups for two weeks. I used GeoGebra embedded teaching module for experimental group and conventional teaching method for control group. Before starting my teaching experiment, I oriented students in GeoGebra for four days. During the teaching learning activities, I mostly motivated students for their active engagement and self-exploration. I always followed the ACE cycle of APOS theory in classroom. During the experimentation, I also noted the students' activities which would be useful for the qualitative part of my study. In the third phase, I conducted post-test for both experimental and control groups with the same test. I also interviewed four students about their experiences on using GeoGebra software. In this phase, I collected data from test, interview and observation diary for the analysis purpose.I used the method of internal consistency to establish the reliability of the test items. I used the most popular method of testing for internal consistency in behavioral science, that is Cronbach alpha(Drost, 2011) in which reliability coefficient of the test was 0.8.

Both quantitative and qualitative types of data were collected in this experimental research. Quantitative data was collected from achievement test and the data obtained from test was analyzed and interpreted using mean, standard deviation and t-test at 0.05 level of significance. And the qualitative data obtained from interview with students and my observation note on the activities of students during the experimentation was analyzed through general qualitative approach.

Once data from the interview and observation have been collected, the next stage involves analyzing them. On qualitative data the data analysis was almost inevitably interpretive, hence the data analysis was less a completely accurate representation but more of a reflexive, reactive interaction (Cohen, Manion, & Morrison, 2007). My specific procedure was to read the original transcript line-by-line, underlining the responses related to each question that had been asked. Next, I sought to highlight any evident agreements, similarities, and differences among the opinions and standpoints of the interviewees, to mark the places at which they had emerged and to identify a consistent pattern from which different categories and themes would emerge. My other step was to identify the main themes and sub-themes and attach them to the relevant text in the transcripts. The choice of thematic analysis for this research lies in its flexibility, suitability to a pragmatic framework, ease of use, acceptability academically. It provides a rich description of data sets and the ability to highlight similarities and differences across data sets.

Discussion on Findings

In this study, two types of data (quantitative and qualitative) were used. The effectiveness of GeoGebra tool in learning geometry was measured from cognitive and non-cognitive aspects. For the cognitive part, quantitative data obtained from pre-test and post-test were analyzed and interpreted and for non-cognitive part different themes were developed such as: social interaction, self-exploration, visualization and understanding. The data obtained from interview and observation note was analyzed under these themes making different sub-headings.

Student's Achievement in Pre-test

In order to make two groups comparable, pre-test was conducted. The pre-test score of both experimental and control group is presented in Table 1. Mean, standard deviation, variance, and t-value are presented in the table.

Table 1.*Pre-test Result*

Groups	N	Mean	Std. Deviation	F	t	Sig. (2-tailed)
Experimental	30	6.23	2.45	2.51	-0.597	.553
Control	31	6.58	2.07			

The data on Table 1 shows that the mean, standard deviation and variance of both group are slightly different. But the difference between the mean score is not significant *(t= -0.597, p=0.553>0.05)*. That means the students in both groups were homogeneous in terms of their achievement.

Student's Achievement in Post-test result

After teaching the experimental group,the certain treatment to experimental group students were assessed with the same tools as post-test. The duration of two test was one month. In order to control the history and testing threats of validity this duration was maintained. Table 2 shows the students' performance in the post-test.

Table 2.*Post-test Result*

Groups	N	Mean	Std. Deviation	F	t	Sig. (2-tailed)
Experimental	30	19.27	3.78	3.870	6.428	.000
Control	31	13.71	2.92			

The result of post-test shows that the mean score of experimental group (Mean=19.27) is higher than the control group (Mean=13.71). The standard deviation of both groups is almost the same. Furthermore, the calculated t-test value (t=6.428) is significant at $p=0.000<0.05$. Hence, it can be concluded that the average achievement score of experimental group is significantly higher than the control group score. That means, the GeoGebra embedded instruction is more effective to improve the achievement of the students in geometry.

Students' Views on GeoGebra Embedded Instruction

Effectiveness cannot be measured only through test score. This is only the cognitive aspect of learning. There are so many non-cognitive aspects of learning which are very crucial in learning mathematics. In this study, some facets of mathematics learning (interaction, self-exploration, visualization and understanding) were also explored during the observation and interview. So, in this section the analysis of these aspects are presented.

Interaction. Interaction is the way people talk and act with each other. It may include interaction in a team, relationship between two or more individuals. Peer to peer interaction and students-teacher interaction are very important in learning mathematics as well. As Vygotsky (1978) explained, social interaction is the important part of learning. Through interaction students can get important mathematical ideas from skillful tutor and friends. In my observation during the GeoGebra embedded instruction students seemed very interactive and questioning mood. They were very busy in doing the task presented in the classroom. The interesting thing I felt during my presentation that they seemed very attentive and asked questions if any confusion arose in my presentation. The classrooms were very interactive and lively.

During interview, I had also asked their previous habits about the interaction in the classroom with teacher and student. One of the respondentswho seemed very interactive in the classroom replied that:

> *I rarely asked question to the teacher and students. But in doing mathematics using GeoGebra I found so many new things which we can visualize, so became very excited and curious about new things. From these classes I became very interactive in the classroom.*

From this short conversation and my observation during experimentation, I came to conclude that ICT integration in teaching learning activities creates the interactive environment in classroom. This is very important for effective understanding of the concept on mathematics.

Self-exploration. In geometry there are so many areas where we need to explore the relationships between different geometrical concepts. During experimentation, I found most of the students engaging in their work. In doing construction in GeoGebra some of the students presented very interesting and dynamic relations between different concepts of geometrical objects. Regarding the views on self-exploration of students on solving problem in geometry, student A opined that:

> *in visualizing the problems and solution through GeoGebra I started to think on the alternatives ways and solution, I focused on to connect my existing idea to tangible example." Another student expressed that, "after I learned some techniques in GeoGebra I have spent more hours in home as well in exploring the ideas of geometry through GeoGebra.*

The use of technology, particularly, GeoGebra helps to scaffold and to bridge the zone of proximal development of student, which enables students to project their actual learning level and help to achieve the principles of constructivist learning (Shadaan& Kwan, 2013). To explore new idea and concept in solving the problems in mathematics needs more time. From the above expression of students, it can be said that GeoGebra helps students engaging in the task related to mathematics. If students are engaged in the problem, they can explore their own idea to solve the problems. In my view GeoGebra embedded instruction is very helpful in students' engagement in learning and self-exploration of the ideas.

Visualization and understanding. In mathematics learning, visualization can be a powerful tool to explore mathematical problems to give meaning to mathematical concepts and the relationship between them. In accordance to Zimmermann and Cunningham (1991), visualization is the ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds, on paper or in technological tools. The purpose of visualization in mathematics is to depict and communicate the idea. In this sense, ICT can be the powerful weapon to visualize the mathematical ideas which are thought to be abstract. Through GeoGebra we can visualize many of the mathematical ideas which essentially assist to understand the concept.

In my observation during experimentation as explained by Shadaan and Kwan (2013), students seemed very exciting and happy to see different geometrical illustration in GeoGebra. They expressed during the class that they never thought about the visualization of the theorem they only proved in the copy and remember the steps of proof. They didn't know that we can visualize every mathematical concept through the use of technology. In one day, I presented the area of parallelograms with same base is equal through GeoGebra. I showed the experimental and theoretical proof both in GeoGebra, then students became very happy to see this. They themselves did this theorem with their own effort as well. After that they shared that they became very clear about the theorem. On one hand, GeoGebra helps to visualize the abstract geometrical theorem which is very effective to understand the concept and on the other hand in doing mathematics in GeoGebra they became very motivating and self-learners which is another important impact of technology in learning mathematics.

Conclusion and Implications

Still, there is the debate in the usefulness of the technology in teaching and learning mathematics. Some of the mathematicians still advocate that the use of technology in learning mathematics kills the creativity and skills of the students. On the other hand, there is strong and research based voice that technology does not kill the creativity and skills of the students in solving the mathematical problems but it enhances and produces creativity. My research findings also support such types of voices. My findings show that the students' achievement in geometry using GoeGebra is significantly higher than that of the conventional teaching method group. In addition to that, there are some skills which are crucial in learning mathematics such as interaction, self-exploration, visualization and understanding are developed within the students while using GeoGebra in teaching and learning geometry. Finally, I conclude that technology is not minimizing the roles of teachers and students. It is becoming the powerful tools to be a teacher and students more creative and self-explorative in their learning.

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