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CONCEPTUAL UNDERSTANDING OF DEFINITE INTEGRAL: AN EXPERIMENTAL STUDY USING GEO-GEBRA AT UNIVERSITY LEVEL

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ABSTRACT

The purpose of this study was to investigate the effectiveness of GeoGebra software on students' achievements regarding their conceptual understanding of definite integral. This study used a quasi-experimental with a pretest-posttest non-equivalent group design. The participants were fifty-two students from two intact sections of postgraduate in the second semester at the University Campus, Kirtipur, with one section assigned as the experimental group and the other section as the control by a convenience sampling method. The experimental group of 24 students received instruction with the GeoGebra software module, while the control group received the traditional method. The independent sample t-test was used in the analysis of data gathered from CUDIT which was subjected to before and after treatment. The results of this study revealed that there were no significant differences in pre-test mean scores between the experimental and control groups at CUDIT, but there were significant differences in post-test mean scores. These results indicated that the conceptual understanding of definite integral of students in the experimental group outperformed those in the control group. This study recommends that mathematics teachers use the GeoGebra Software for the conceptual understanding of the mathematical content to help learners in their learning process.

Keywords: achievement - conceptual understanding - GeoGebra software - quasi-experiment.

INTRODUCTION

The conceptual understanding of definite integrals (CUDI) at intermediate and undergraduate levels is one of the most fundamental, essential, and important assumptions not only in understanding calculus but also in developing mathematical thinking beyond calculus and in pursuing mathematical rigor knowledge (Ferrini-Mundy & Lauten, 1993; Tall, 1992).The main ideas of calculus were independently found by Newton and Leibniz in the 17th century. Calculus means "small stones" because it's like understanding something by looking at small pieces (Malhotra & Gupta, 2011). It is divided in two branches, differential and integral calculus. Differential calculus has problems with how things change with respect to time, while integral calculus integrates the small pieces together to find out how many there are (Das & Mukherjee, 1993). The definite integral is the part of integral calculus. It establishes a framework necessary to have a complete acquisition of the basic concepts of calculus related to ant-derivative, indefinite integral of a continuous function, the Fundamental Theorem of calculus and, its application to many calculus problems (Thompson et al., 2013). Therefore, the definite integral concept should have been the focus of various researches. The conceptual understanding of the definite integral holds a central position in mathematical analysis, integral calculus and complex analysis (Cornu, 1991). According to Tasman et al., (2019) in learning definite integral, students have to understand about Sigma, Riemann sum, limit and area. These concepts are used to build the concept of definite integral. He believes that this conceptual understanding is a particularly difficult idea, typical of the type of thinking required in advanced mathematics. Due to the above-mentioned importance of definite integral, a considerable amount of research has been conducted on this concept. Most of the research revealed that students face problems while learning definite integral concept in their courses (Williams, 1991). Thus, teachers at universities must be aware of how students have created their early conceptions of definite integral and try to offer opportunities to develop these, often limited and insufficiently matured, conceptions to more meaningful concepts.

In Nepal, the concept of definite integral is also taught for students at secondary and university levels. In the literature, it is documented that the concepts of limit, derivatives and integral are generally difficult, while the concept of definite integral is even harder for most of the students'(Delice & Sevimli, 2010). Learning definite integral concept may not be easy and large number of students fails to develop an adequate understanding, reasoning, and problem-solving skill in it. According to Winarso and Toheri, (2017) the lack of conceptual understanding in learning definite integral often causes discouragement among the students, which invariably will lead to poor performance in calculus and claimed that some factors have been identified causing the difficulties in learning definite integral, those are the teaching materials used by teachers, classroom management, content knowledge, geometry language, visualization abilities and teaching methods. The conceptual understanding of definite integral can be considered a difficult topic. In the typical classroom, the challenge for students is to explore complex problems. With the advancement of multimedia technology, learning difficulties can be overcome. The challenge is more complex in teaching and learning mathematics, where teachers need to balance mental, stationery, and digital tools for teaching and learning that involve abstract mathematical concepts that are difficult for students to understand.

Several studies have been done to develop teaching methods that support the visualization for the rigorous conceptual understanding of the mathematical contents. According to (Kidron & Zehavi, 2002) affirm the effectiveness of dynamic images in learning the concept of definite integral and suggest computer animation as a powerful visual interpretation of the dynamic image of it. The study by Pinto and Tall, (2002) also revealed that visual images play a positive role in teaching and learning about real analysis. Likewise, Navarro and Carreras (2006) have shown that a visual pedagogical method would not only help students build a relevant conceptual image of boundaries, but it would also help students move towards a more rigorous mathematical definition. A number of studies have demonstrated that information and communication technology (ICT) has a positive impact to develop spatial skills. According to Harrison et al. (2002), there is a positive relationship between the use of ICT and students' performance. Nakhleh and Krajcik, (1994) discovered that using ICT in teaching and learning activities helps to develop the concept. Another study from Tunun et al. (2009) shows that there is a relational effect of ICT on students' performance and also helps motivate students to learn. The ICT tools helps to the teachers and students to communicate abstract mathematics concepts in conceptually rich, build new knowledge and explore new approaches for the conceptualization of it (Bray & Tangney, 2017). Technological literacy is an important skill that should be emphasized in mathematics classes at all level (Mainali & Key, 2012). Teachers must have a deep knowledge of ICT tools available to them in order to properly utilize their abilities to create activities that completely engage students in learning (Sherman, 2014). Therefore, using ICT simulations increases the students' performance on the learned concept. Thus, it could be an alternative teaching method which cultivates a purposeful conceptual understanding of mathematical concepts.

Yismaw and Gurju (2018) stated that integrating the ICT tools into the teaching and learning of mathematics addresses the learning requirements and interests of many of our students in an interconnected society. Our students' learning methods are influenced by technology. Through modeling, simulation, and visualization, they prefer to see, touch, and feel the things they learn about in school (Akcay, 2017). ICT tools make it possible for teachers and students to communicate abstract mathematics concepts in conceptually rich, build new knowledge and explore new approaches for the conceptualization of it (Bray & Tangney, 2017). Technological literacy is an important skill that should be emphasized in mathematics classes at all level (Mainali & Key, 2012). Teachers must have a deep knowledge of ICT tools available to them in order to properly utilize their abilities to create activities that completely engage students in learning(Sherman, 2014). According to NCTM,(2000), Information and Communication Technology (ICT) is essential powerful resources in teaching and learning mathematics. It makes easy to understand new concepts, knowledge, skill related to daily life circumstances. The system of education has been affected by technology. New technologies challenge traditional designs and ensuring new concepts in the teaching-learning process and it can influence the mathematics that is taught and enhances students' learning. Besides that, technology can also help students to furnish their visual images of mathematical ideas, organizing and analyzing data, and can compute efficiently and accurately. Technology can support students to investigate in every area of mathematics, such as geometry, statistics, algebra, measurement and calculus (NCTM, 2000).

There are various types of mathematical software available to facilitate teaching and learning mathematics. For example, Geometer's Sketchpad, Derive, Cabri, Matlab, Autograph, GeoGebra, Mathematica, and others. This mathematical software has been used in schools and also at university levels worldwide. Nepal is a developing country, so technological or digital dives are not very developed (Joshi, 2016). Therefore, it has difficulties being used in the mathematics classroom due to financial difficulties, awareness, availability, appropriate policies, and integration issues. However, Geogebra software is freely available and used by educators in their mathematics classroom teaching.

STATEMENT OF THE PROBLEM

Despite the significant benefits of using ICT to enhance students' mathematical learning by providing a great opportunity for visualization, manipulation, and exploration of mathematical concepts, a significant number of students at the university level continue to struggle with how to effectively use it for everyday learning. Despite the fact that students have access to Geogebra software and other related software is generally available, technology in mathematics classrooms is rarely incorporated meaningfully into regular teaching and learning activities. According to some research, it has been shown that teachers' knowledge of both technical and pedagogical reasons has a major impact on their inclination to use technology.

According to the Department of Mathematics Education's internal evaluation reports for the past two academic years, students' underachievement in the complex analysis course was due to a lack of conceptual understanding of definite integrals. Therefore, the present study is to investigate the effectiveness of GeoGebra software in teaching the definite integral on the postgraduate students. The emphasis is to discover whether the GeoGebra-software teaching method enhances students' conceptual understanding of definite integrals and improves their achievement in definite integrals. Hence this study attempts to examine impact of Geogebra software on the achievement of postgraduate level students in conceptual understanding of the definite integrals.

RESEARCH HYPOTHESIS

This study was carried out in order to investigate the effectiveness of GeoGebra software about the students' achievement in conceptual understanding of definite integral. Therefore, the following research hypotheses were purposed:

a) H_{01}: There is no significant difference in the mean scores between pre-test of the experimental and control groups students at CUDIT.
b) H_{02}: There is no significant difference in the mean scores between post-test of the experimental and control groups students at CUDIT.

METHODOLOGY

This study used a quasi-experimental with a pretest-posttest non-equivalent group design. This design was the most effective since it attempted to investigate the treatment's influence on intact groups rather than randomly assigning the experimental or control groups (Fraenkel et al., 2012). Pretest - posttest non-equivalent groups is a design that divides an experimental group and a control group, which are compared using pretest and posttest measures. The experimental group is given treatments by using GeoGebra Software, but the control group is not. Cohen et al., (2007), defines the figure of the pretest and posttest groups design was shown in the Table 1.

Table 1: The summary of research design

Groups	Pre-test	Intervention	Post-test
Experimental	CUDIT	Teaching with GeoGebra	CUDIT
Control	CUDIT	Teaching with Traditional Method	CUDIT

In the department of mathematics education in the faculty of education at the University Campus Kirtipur of Nepal, a total of 52 students were enrolled regular in two sections. In section "A," there were 24 students, and in section "B," there were 28 students. The convenience sampling method was used to conduct the study(Cohen et al., 2007). Section "A" is the experimental group, which received Geogebra software integrated teaching, and section "B" is the control group, which received traditional instruction method. In this study, there are two variables, independent variable and dependent variable. Independent variable is GeoGebra Software integrated teaching method and the dependent variable is students' achievement and other affecting variables such as teachers, time duration of teaching, content, evaluation techniques and socio-economic factors were tried to control as for as possible. Creswell, (2014) argued that independent variable is an attribute or characteristic that is dependent on or influenced by the independent variable. The effect of instruction with GeoGebra on students' conceptual understanding of definite integral was compared to the effect of traditional instruction with this design. The researcher wished to go through the three phases of the study that were the pre-experimental phase, experimental phase, and post-experimental phase. In the pre-experimental phase, first the researcher prepared eight GeoGebra software integrated teaching modules to provide a conceptual understanding of the definite integral. It takes 55 minutes to complete each module and the conceptual understanding of the definite integral test (CUDIT) for per-test and post-test, which are the main data collection tools used in this study. This test consists of ten subjective questions modified to measure conceptual understanding of definite integrals from complex analysis (Adhikari, 2021). This test had a total score of 50, with each question receiving an equal value. The Cronbach alpha (Drost, 2011) was employed as the most common way of testing for internal consistency in behavioral science, and the test's reliability coefficient was 0.78. Also, researcher conducted pre-test for both experimental and control groups using the CUDIT, which completed within 55 minutes. During the experimental phase, the researcher taught both groups about the concept of definite integral for eight days. Researcher used GeoGebra integrated teaching module for the experimental group and a traditional teaching method for the control group. During the teaching and learning activities, researcher mostly motivated by their active engagement and self-exploration and followed the APOS theory in the classroom. In the third phase, researcher conducted post-test for both experimental and control groups using the same test, which completed within 55 minutes.

Table 2 and Table 3 shows that all sig. values in Shapiro-Wilk Test for both experiment and control group students' scores acquired from conceptual understanding of definite integral in pretest and posttest of CUDIT were greater than p=0.05 level of significance. As a result, the independent sample t-test assumption of normality was satisfied (Tabachnick & Fidell, 2019). Furthermore, Levene's test for equality of group variances revealed that the sig. values of p for both group experiment and control group students' scores acquired from conceptual understanding of definite integral in pretest and posttest of CUDIT were greater than the p=0.05 level of significance. As a result, the homogeneity of variance assumption was met as well (Tabachnick & Fidell, 2019).Therefore, all assumption underlying independent samples t-test were met.

Table 2: Shapiro-Wilk test and Levene’s test results to ensure the assumptions of normality and equality of variances for experimental and control groups students’ scores in pre-test of CUDIT

Groups	Shapiro-Wilk Test (Assumption of Normality)			Levene’s Test for Equality of Variances	
	Statistics	**Df**	**Sig.**	**F**	**Sig.**
Experimental	0.963	24	0.507	0.000	0.989
Control	0.943	28	0.135		

Table 3: Shapiro-Wilk test and Levene’s test results to ensure the assumptions of normality and equality of variances for experimental and control groups students’ scores in post-test of CUDIT

Groups	Shapiro-Wilk Test (Assumption of Normality)			Levene’s Test for Equality of Variances	
	Statistics	**Df**	**Sig.**	**F**	**Sig.**
Experimental	0.923	24	0.069	4.005	0.051
Control	0.943	28	0.231		

The effectiveness of instruction with using GeoGebra on students’ learning of conceptual understanding of the definite integral was investigated by using the independent sample t-test, and the effectiveness of GeoGebra software was interpreted as in Table 4. Thus, the SPSS 26 version was used to analyze and interpret the data obtained from CUDIT on pre-test and post-test scores using the mean, standard deviation, and independent sample t-test at the 0.05 level of significance.

Table 4: *Interpretation for effect size*

Effect size (eta squared, η^2)	Interpretation
$0.01 \le \eta^2 < 0.06$	Small significance
$0.06 \le \eta^2 < 0.14$	Intermediate significance
$0.14 \le \eta^2$	Large significance

Source: Cohen, 1988

RESULTS AND DISCUSSION

An independent sample t-test was used to assess if there were any significant differences in the pre-test mean scores of both the control and experimental groups.

Table 5: Independent sample t-test results for experimental and control groups students' pre-test scores in CUDIT

Groups	N	Mean	Std. Deviation	F	t	Sig.(2-tailed)	Effect Size
Experimental	24	30.42	2.60	0.99	1.20	0.24	0.03
Control	28	31.25	2.39				

The analysis of the information mentioned in the above Table-5 represents that the mean pre-test score of experimental (n = 24) and control (n = 28) students was compared using an independent sample t-test. The premise of normality was not broken because Shapiro-Wilk statistic was no statistically significant. Levene's test was also non-significant, implying that both groups have the same variance. Thus, the independent sample t-test results indicate that there was no statistically significant difference the mean pre-test score of experimental group (M=30.42, SD=2.60) compared to control group (M= 31.25, SD= 2.39; t (50) = 1.20, p= 0.24 > 0.05). The difference between the mean is 0.83 point on a 50 points-test. The effect size (eta squared, η^2) is approximately 0.03, which is considered to be small effect size(Cohen, 1988). This finding showed that the conceptual understanding of definite integral of the control and experimental groups students have no significance differences.

Effectiveness of using GeoGebra software on students' conceptual understanding of definite integral

To determine whether any significant differences existed between the post-test mean scores of the control and experimental groups, an independent sample t-test was done.

Table 6: Independent Sample t-test Results for Experimental and Control Groups Students' Post-test Scores in CUDIT

Groups	N	Mean	Std. Deviation	F	t	Sig.(2-tailed)	Effect Size
Experimental	24	41.00	1.22	4.01	-15.45	0.00	0.83
Control	28	33.89	1.95				

The analysis of the information mentioned in the above Table-6 represents that the mean pre-test score of experimental (n = 24) and control (n = 28) students was compared using an independent sample t-test. The premise of normality was not broken because Shapiro-Wilk statistic was no statistically significant. Levene's test was also non-significant, implying that both groups have the same variance. Thus, the independent sample t-test results indicate that there was statistically significant difference the mean post-test score of experimental group (M = 41.00, SD = 1.22) compared to control group (M = 33.89, SD = 1.95; t (50) = -15.45, p= 0.00 < 0.05). However, the mean score of the experimental group students is higher than students in control group by 7.11 points on 50 points-test. The effect size (eta squared, η^2) is approximately 0.83, which is considered to be large effect size (i.e. significant effect size)(Cohen, 1988). This finding showed that students who had learned the definite integral using GeoGebra software was significantly better in their conceptual understanding of definite integral compared to students have who underwent the traditional learning. It's consistent with the results conducted by Kado and Dem(2020), Hodanbosi (2001), Sur (2020), Zulnaidi and Zakaria (2012)Tatar and Zengin (2016), and Tasman et al., (2019a). In particular, GeoGebra software keeps mathematics from becoming abstract by assisting students in visualizing and concretizing concepts, relationships between concepts, learning by doing, and providing a learning environment in which students can practice, all of which contribute to improved conceptual understanding of the definite integral.

CONCLUSION

The aim of this study was to investigate the effectiveness of GeoGebra Software on the conceptual understanding of definite integral. The results of the independent sample t-test on it revealed two primary findings. The first was that there were no significant differences in CUDIT pre-test mean scores between the experimental and control groups, while the second was that there were significant differences in CUDIT post-test mean scores between the experimental and control groups. These results indicate that GeoGebra Software is a useful tool in enhancing the conceptual understanding of the mathematical content, particularly in learning about definite integrals. This software also allowed teachers and students to collaborate on the topics by allowing them to explore and visualize them together. This encouraged a more involved teacher-student interaction atmosphere in which everyone worked together as a team to lead, help, and assist one another in achieving the desired outcomes. As a result of the findings of this study, Nepalese instructors should be encouraged to adopt the free source GeoGebra software, which aids in the visualization of abstract mathematical content in teaching and learning activities at various levels of mathematics classrooms.

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