Effectiveness of GeoGebra in Developing the Conceptual Understanding ofDefinite Integral at Gongzim Ugyen Dorji Central School, in Haa Bhutan.

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ABSTRACT

As recommended by the Education Blueprint 2014-2020, education system in Bhutan transformed from traditional instructions to technology-enriched and enabled teaching and learning environment with adoption of emerging and relevant technology to produce the globally competent learners**.** The integration of educational technology in the teaching and learning of definite integral creates a conceptually rich learning environment. From this perspective, this study aims to ascertain the effectiveness of a computer-assisted instruction method using GeoGebra in developing the conceptual understanding of definite integral for grade 12 students. This study employed a quasi-experiment static-group comparison design with 60 students from Gongzim Ugyen Dorji Central School in Haa. The students were divided into two equal groups. Group ‘A’ used the GeoGebra software, while group ‘B’ used the conventional method to learn definite integral. The data were collected through Definite Integral Knowledge Test. An Independent sample t-test was employed using the Statistical Package for the Social Sciences (SPSS 22.0). Findings of the study showed that students who were taught using GeoGebra outperformed those who learned through conventional methods. The results confirmed that GeoGebra software is capable of enhancing and significantly improving students’ conceptual understanding of definite integral.

Key words: Calculus,Definite Integral, Conceptual understanding, GeoGebra,

1. INTRODUCTION

The ideas of the calculus were independently discovered by Newton and Leibnitz in 17th century. Calculus means, "Small Stones" because it is like understanding something by looking at small pieces (Malhotra, Gupta & Gangal, 2016). It is divided into two branches, differential and integral calculus. Differential calculus concerns with how things change with respect to time, while integral calculus integrate the small pieces together to find how much is there (Integral calculus, n.d.)

Calculus is considered as vital topics in mathematics due to widespread application across the multidisciplinary fields such as biological sciences, physical sciences, engineering, social sciences, and economics (Arini & Dewi, 2019). Considering its significance, it is paramount to focus the teaching and learning of integral calculus on developing the relational understanding/conceptual understanding instead of instrumental or mechanical understanding. From our search of the literature, it is clear that new calculus courses should place less emphasis on complex skills and emphasize conceptual development (National Council of Teachers of Mathematics [NCTM], 2014).They also recommended future research to focus on enhancing the conceptual development as this understanding can have a profound impact on students' ability to solve in definite integral.

Despite the importance of the emphasizing the teaching and learning of calculus on conceptual development, the conventional teaching and learning of definite integral that relies on symbols and notations, has been the preferred method of calculus instructions for decades. There is a body of evidence that suggest that teaching and learning of definite integral focus more on computational process rather than underlying concepts that resulted in routine algebraic manipulations (Lasut, 2015; Theodosis, Pamifilos, Christous, Maleev & Jones, 2007). Thus the traditional approach of teaching and learning helps to develop the skills of manipulating algebraically, understanding instrumentally and memorizing the formulae instead of comprehending conceptual or relational proficiencies.

In literature, there is broad theoretical and experimental evidence to support that limit, derivative, and integral are epistemologically difficult concepts for the learners, while the concept of definite integral is even harder for learners(Dergisi, Del, & Kelimeler, 2010; Orton, 1983; Rasslan & Tall,2002; Serhan,2015). Learners could correctly use operational knowledge to manipulate the algebraic functions symbolically, but they fail to interpret meaning.In a study that explored students' understanding of definite integral concept, Serhan(2015) found that most students' do not have sufficient conceptual understanding of definite integral, their dominant knowledge was the procedural knowledge and their ability for multiple representation of concepts were limited.Mahir (2009)administered a questionnaire that aimed at investigating students' understandings of the concepts associated with the definite integral as well as their computation skills. Mahir found that students' understanding of definite integral is rather instrumental or mechanical.Despite the wealth of literature available in this field in international context, there are limited academic discourse in the Bhutanese context that focus on developing the conceptual understanding of definite integral. Thus, this research attempts to enhance students' conceptual understanding of definite integral using the GeoGebra.

GeoGebra is open-source software developed by Markus Hohenwarter in 2002 for teaching and learning Mathematics from primary to the university level(Hohenwaeter, Jarvus, & lavicza, 2009). It combines many aspects of different mathematical packages, and dynamically joins Geometry, Algebra and Calculus. The numerous calculus- related interactive worksheets and methods developed by teachers and researchers are available (www.geogebra.org). Based on the site, GeoGebra users have reached 100 million students, while GeoGebra researchers based on Google Scholar have 15,800 published scientific papers(Arini & Dewi, 2019).

Studies have shown that an improvement in calculus concept can be achieved by integration of educational technology in teaching and learning as it have potential to have positive impact on students' conceptual understanding of calculus (Arini & Dewi, 2019, Berry, et al., 2008).Realizing the efficacy of technology enriched and enabled learning environment , Bhutan Education Blueprint 2014-2020 recommended a shift in educational system by leveraging ICT to produce globally competent learners to address the need of fourth industrial revolution. Subsequently, Ministry of Education launched its education ICT master plan called iSherig, on May, 2019, to harness the potential benefit of ICT in teaching and learning by creating a platform for effective communication, enabling access to information and knowledge, and conceptually rich learning environment where students construct their own knowledge, visualize and experiment.

As enshrine in our Education Blue print 2014-2020, teachers in Bhutan embarked the journey of embracing educational technology to enhance teaching and learning. The educational technology like GeoGebra software chosen as a teaching method has the potential to visualize the conceptual definition of definite integralas the limiting process.Further support is given by Arini & Dewi(2019) that generally asserts that GeoGebra is a digital tools that helps to develop the concept image of definite integral and helps to visualize the abstract concept algebraically, numerically and graphically. The embeddedmixed method design study showed that the computer assisted instructions method using GeoGebra had significant influence on teaching and learning outcome of definite integral. Additionally, this study found to facilitate conceptual learning of the definite integral(Tatar & Zengin, 2016).Zulnaidi & Zakaria (2012) conducted a quasi-experimental study to investigate the efficacy of developing conceptual understanding and procedural knowledge of 124 high school students in Indonesia. The finding revealed that treatment group showed significant gained in conceptual knowledge compared to control group.

In nutshell, it is clear from the extensive evidences in literature that students' knowledge was rather an instrumental or mechanical as they know how to manipulate the algebraic expression symbolically but had complexity in elucidating the meaning. The present study was designed to enhance learners' conceptual or relational understanding in definite integral. Based on literature research, no similar study was conducted in Bhutan; therefore, our study sheds light on the efficacy of digital tools like GeoGebra having significant impact for acquiring conceptual knowledge in definite integral. This study also serves as stepping stone for further investigation of efficacy of GeoGebra in mathematics in general, calculus in particular.

1.1 Objectives of the Study

This study has two main objectives:

i. Developing the Conceptual or Relational Understanding of Definite Integral
ii. To compare the conceptual knowledge of students in treatment and control groups

1.2 Research Questions

What is the impact of GeoGebra software on the achievement of conceptual understanding of the definite integrals?

2. MATERIAL AND METHODS

This study used a quasi-experimental static-group comparison design to compare the effectiveness of the GeoGebra in developing the conceptual understanding of definite integral for the students who received GeoGebra enriched instructions and students who received traditional instructions. This method was the best approach as it attempts to study the effect of the treatment on intact groups rather than being able to randomly assign participants to the experimental or control groups(Creswell,2013; Mertens,2010)

The participants consist of 94 students from grade 12 mathematics students at Gongzim Ugyen Dorji Central School.The cluster random sampling was adopted to select 60 out of 94 students from 3 sections. The students were then divided into two groups; one was a treatment group and the other was the control. Students in the treatment group were taught definite integral using the GeoGebra software. Students in the control group were taught through normal conventional learning.

A Definite Integral Knowledge Test (DIKT), consisting of six questions modified from BHSEC Mathematics Book-II for Class XII students of Bhutan were used to collect the data (Malhotra, Gupta, & Gangal, 2020). . Instrument was piloted to ensure its reliability and validity. The average Item objective Congruence (IOC) was 0.89, validating the appropriateness for the study. The reliability of the instrument was proven high with item reliability of 0.88. Comparative statistical analysis was done using the t-test. The independent sample t-test was used to compare the learning achievement between the control and experiment group. The inferential t-test with $p<0.005$ level of significance, the mean and standard deviation were used to infer the results.

3. FINDINGS

Before conducting the inferential *t-test*, the normality test were conducted using Kolmogorov-Smironov test as shown in the table 3.1. The findings of Kolmogorov-Smironov analysis for the degree of normality assumptions was satisfied for both pre-posttest of EG and CG $(P > 0.05)$. Additionally Levene's test for equality of variances of scores for two groups (EG& CG) were conducted as shown in the table 3.2

Table 3.1 . Test of normality with One-Sample Kolmogorov-Smirnov Test

	Pretest-EG	Posttest-EG	Pretest-CG	Posttest-CG
N	32	32	30	30
Kolmogorov-Smirnov Z	.978	.944	.986	1.406
Sig. (2-tailed)	.294	.335	.285	.038

Significant level: >0.05—no significant, <0.05—significant

Table 3.2. Levene's test for equality of variances

		F	df	Sig.
Pre-test	Equal variances assumed	6.571	62	0.78
	Equal variance not assumed		58.99	
Post-test	Equal variance assumed	17.714	62	
	Equal variance not assumed		42. 73	0.00

Significant level: >0.05—no significant, <0.05—significant

The Levene's test indicated that the assumption of homogeneity of variance of pre-test was met as p value is greater than 0.05$(F(1,62) = 6.571, p = 0.78)$ .However, the variation of post-test scores for both the groups was not same as p-value is less than 0.05 $(F(1,42.73) = 17.714, p = 0.00)$. Thus, the assumption of equal variances had been violated.

3.1 Comparisonof Pre-test and post-test scores of DIKT

An independent sample t-test was conducted to determine the difference in DIKT between the experimental and control group as shown in the table 3.3.

Table 3.3. Independent Sample t-test

Test	Group	Mean	Mean Difference	Standard Deviation	Sig. (2 tailed)	Effect Size
Pre-test	Control	7.58	0.391	6.10	0.778	0.006
	Experimental	7.59		5.96		
Post-test	Control	23.83	33.125	10.52	0.000	0.91
	Experimental	56.95		4.66		

Significant level: >0.05—no significant, <0.05—significant

An independent- samples t-test was conducted to compare the pre-test scores for EG and CG. There was so significant difference in scores for pre-test for Experimental (M= $7.59, SD = 5.96$) and Control group, $M = 7.58, SD = 6.10; t(62) = -0.283, p = 0.778$(two tailed). The magnitude of the differences in the means (MD= $0.391, 95\%CI$:-3.147 to 2.366) was very small (eta squared= 0.006). This means that the data were homogeneous and treatment could be applied to these groups to identify differences caused by the treatment.

An independent sample t-test conducted for comparison of post-test scores between experimental and control group showed significant mean difference between EG ($M = 56.95, SD = 4.66$) and CG (M $= 23.83, SD = 10.52); t(42.730) = 16.276, p = 0.000$(two tailed). The magnitude of the differences in the means (mean difference= $33.125, 95\%\ CI: 29.057\ to\ 37.193$) was very high (eta squared $= 0.91$).This indicates that there was a statistically significant difference in post-test scores between experimental and control group. The test scores of an experimental group were significantly higher than the test scores of the control group.

4. DISCUSSION AND CONCLUSION

The results of the independent sample t-test indicated that there were significant differences in DIKT between the experimental and control group. Students in the treatment group had higher conceptual knowledge at post-test compared to the control group. This is because GeoGebra aided instruction supported students' learning meaningfully and conceptually. Moreover, it had potential to visualize and concretize abstract nature of definite integral. This finding is consonance with the study done by Mateus (2018) asserted that GeoGebra mediated instructions effectively promote the conceptual development of Riemann integral. The other significant rise in post test scores can be attributed to ability of GeoGebra to represent the abstract concept graphically. It has been experimentally demonstrated GeoGebra was an effective tools for teaching and learning calculus as it allows students to actively construct their knowledge, multidimensional visualization of concepts and experimentation(Nobre et al., 2016).

The one possible reason for significant improvement of the result was attributed to potential of GeoGebra to make the connection between concept image and concept definition of definite integral. The study conducted by Huang (2015) in Taiwan for the first-year calculus students at university, revealed that the development of visualization ability of students, increases students' performance in solving the problems in the definite integral. The findings also indicated that students taught through multi-dimensional approaches, like the visualization of concepts graphically and algebraically, were able to connect the concept image and concept definition, leading to significant improvement in their learning. This is in line with our study where concepts were developed with computer-assisted graphing tools.

In summary, this research can be considered to be a significant step in adopting GeoGebra in teaching and learning of the definite integral in Bhutanese context. Moreover, this results of the study adds to the growing body of evidence that GeoGebra is an effective educational technology for enhancing the conceptual understanding of the definite integral. Thus, it is paramount to embrace GeoGebra as supplementary tools for teaching and learning calculus in general, definite integral in particular.

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